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SUMMARY OF ECONOMICS FOR VARIOUS REFINERY PROJECTS

Refinery Analysis No.	Crude Capacity BPCD	Gasoline BPCD	Distillate Fuels BPCD	Residual Fuel BPCD	ASTM Octane No.	TEL Ccs/Gal.	Crude Cost ¢/Gal.	By-Product Cost of Gasoline ¢/Gal.	Differential ¢/Gal.	Payout in Years
1	5,000	2,893	1,185	688	83.0	1.9	3.8	4.6	0.8	1.4
2	5,000	2,848	600	1,428	83.5	1.3	3.0	5.0	2.0	2.2
3	5,000	3,281	1,239	286	77.5	1.7	4.2	5.1	0.9	3.5
4	3,000	1,206	870	914	79.0	1.3	4.6	4.9	0.3	2.3
5	6,000	3,673	1,080	1,036	77.5	0.7	3.2	4.2	1.0	3.7
6	4,000	2,842	320	604	79.0	0.7	3.2	4.7	1.5	3.6
7	6,000	3,992	.....	1,566	82.5	0.9	3.0	5.1	2.1	2.9
8	4,000	2,610	400	753	78.0	0.5	3.1	4.6	1.5	2.9
9	12,000	7,787	1,800	1,602	81.0	1.5	2.8	4.0	1.2	1.1
10	5,330	3,812	.....	1,032	80.5	0.5	2.9	4.5	1.6	3.3
11	22,500	15,562	2,250	3,004	80.0	0.6	3.9	5.1	1.2	2.3
12	12,000	5,969	1,025	4,612	82.0	1.1	2.5	3.6	1.1	2.5
13	10,000	5,110	3,963	574	78.0	0.5	3.5	3.9	0.4	1.8
14	3,500	1,764	525	1,069	80.0	1.1	3.1	4.7	1.6	2.2
15	9,000	4,663	2,375	1,662	76.0	0.6	4.6	5.1	0.5	2.2
16	6,750	4,473	1,991	783	81.5	1.5	3.9	4.7	0.8	1.7

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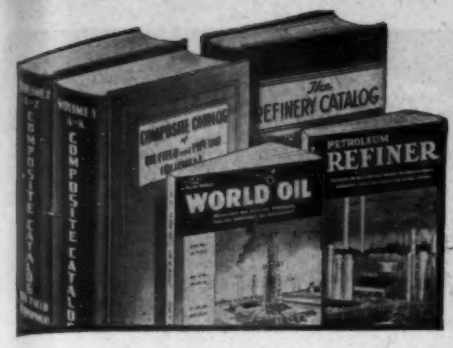

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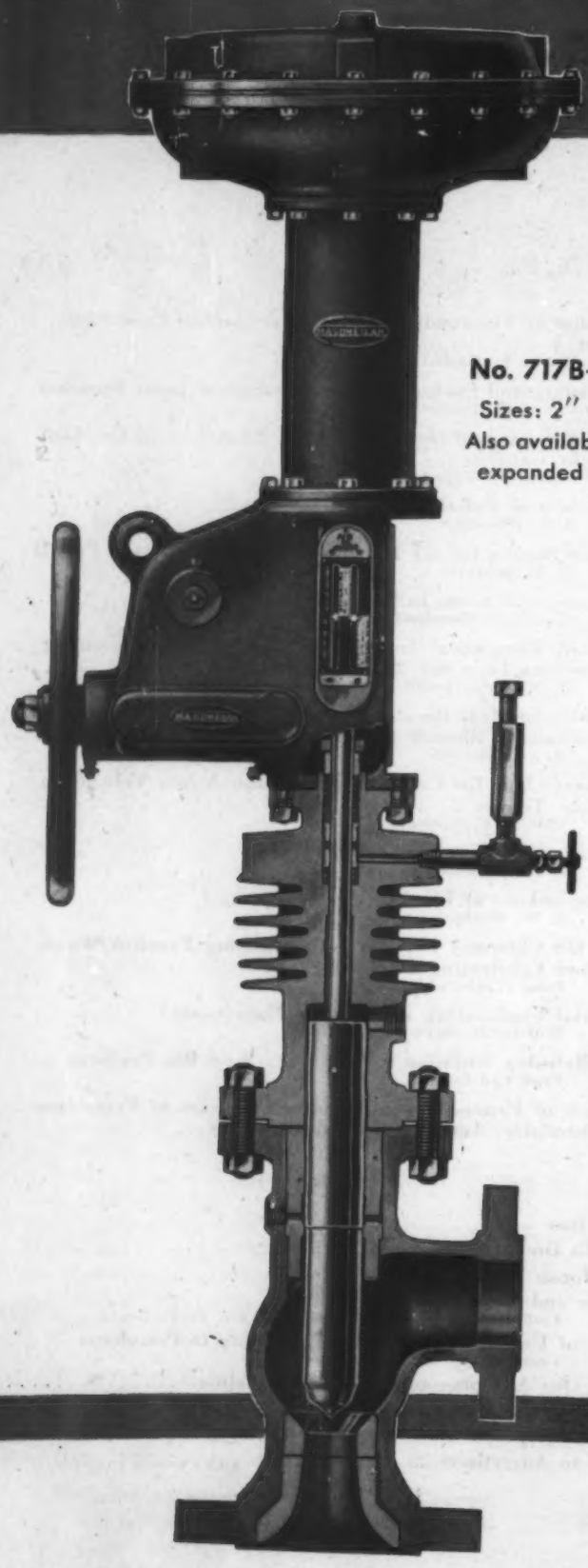

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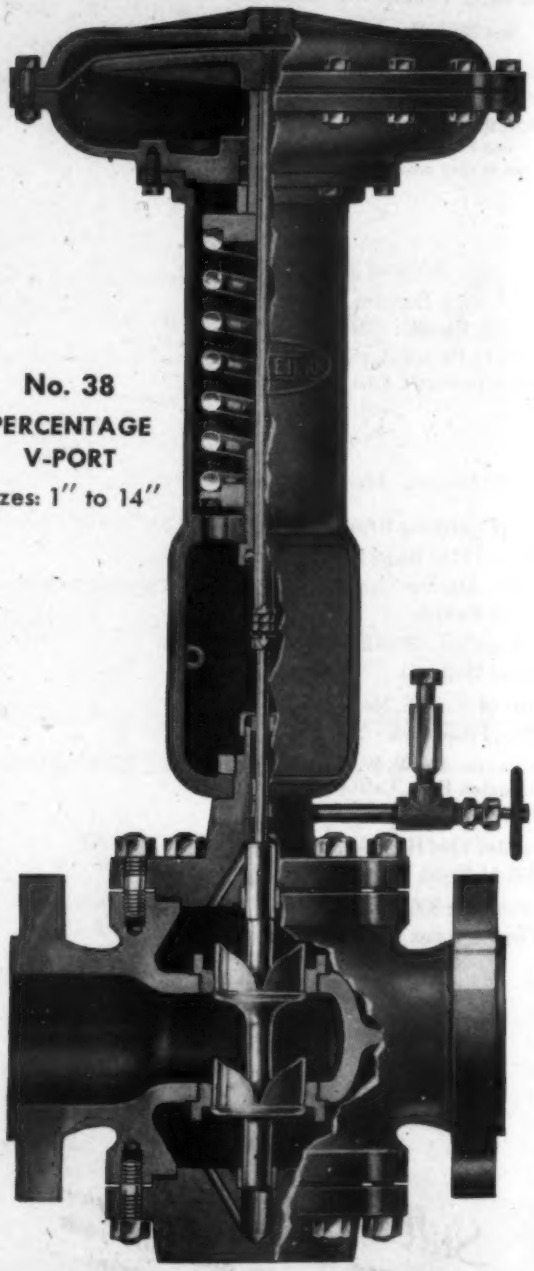

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THE LOOK BOX

SOME comprehension of the unprecedented demand for petroleum products as well as explanation of shortages anticipated for next winter can be had from the summary of Eugene Holman, whose report to stockholders related that domestic runs to still of domestic subsidiaries of Standard Oil Company (New Jersey) for the first five months of 1947 reached 685,000 barrels daily, a gain of 9 percent over the corresponding period of 1946.

Mounting Demand

The trend is typical for the whole industry is now producing and refining crude oil at its highest level, with crude runs to still and well output recently above the 5,000,000 barrels daily limit for the first time since the war period.

The prospect of shortages of finished material lies not in lack of crude oil but in the necessity of completing more pipe lines and more plant capacity. Manufacturing and transportation facilities are the critical points in the affairs of the industry. The domestic and foreign subsidiaries of this one company are spending $228,000,000 in providing necessary facilities.

As for shortages of raw material, Holman singled out the trend toward conversion of natural gas and conversion of coal into liquid products.

Natural gas conversion is expected to increase reserves by 30 percent while conversion of coal places source material for liquid products almost in the unlimited classification. An important factor in this connection, however, is that capital investments for these conversions are large by comparison with costs for ordinary refining equipment.

More recently before the Division of Refining of the American Petroleum Institute, Dr. Robert E. Wilson, chairman of the board of Standard Oil Company (Indiana) said that transportation is the controlling factor in the situation. Completion of several pipe line projects along with refinery expansion programs will in his opinion relieve the situation. He pointed out also, that the industry needs freedom from control and high taxation if it is to provide the funds necessary to keep ahead of demand for its products.

UNDER the current trend the famous Iron Horse shortly will be represented by the diesel engine rather than the steam engine. Right now American railroads are ordering seven diesel-powered locomotives for one steam locomotive. This figure is from a recent issue of *The Lamp*, published by Standard Oil Company (New Jersey), which makes this observation:

Diesel Trend

"This trend calls for advance planning by the oil industry which may be called upon to increase greatly its production of diesel fuels," and further explains reasons for the shift:

"Higher efficiency at lower operating costs is one big reason why railroad men are turning toward the diesel. Fuel combustion releases energy in the form of heat and the measure of an engine's efficiency is the percentage of heat energy in its fuel which it actually transforms into useful work. By this scale, the conventional non-condensing steam locomotive is about 7 percent efficient; the condensing steam engines and steam turbine power

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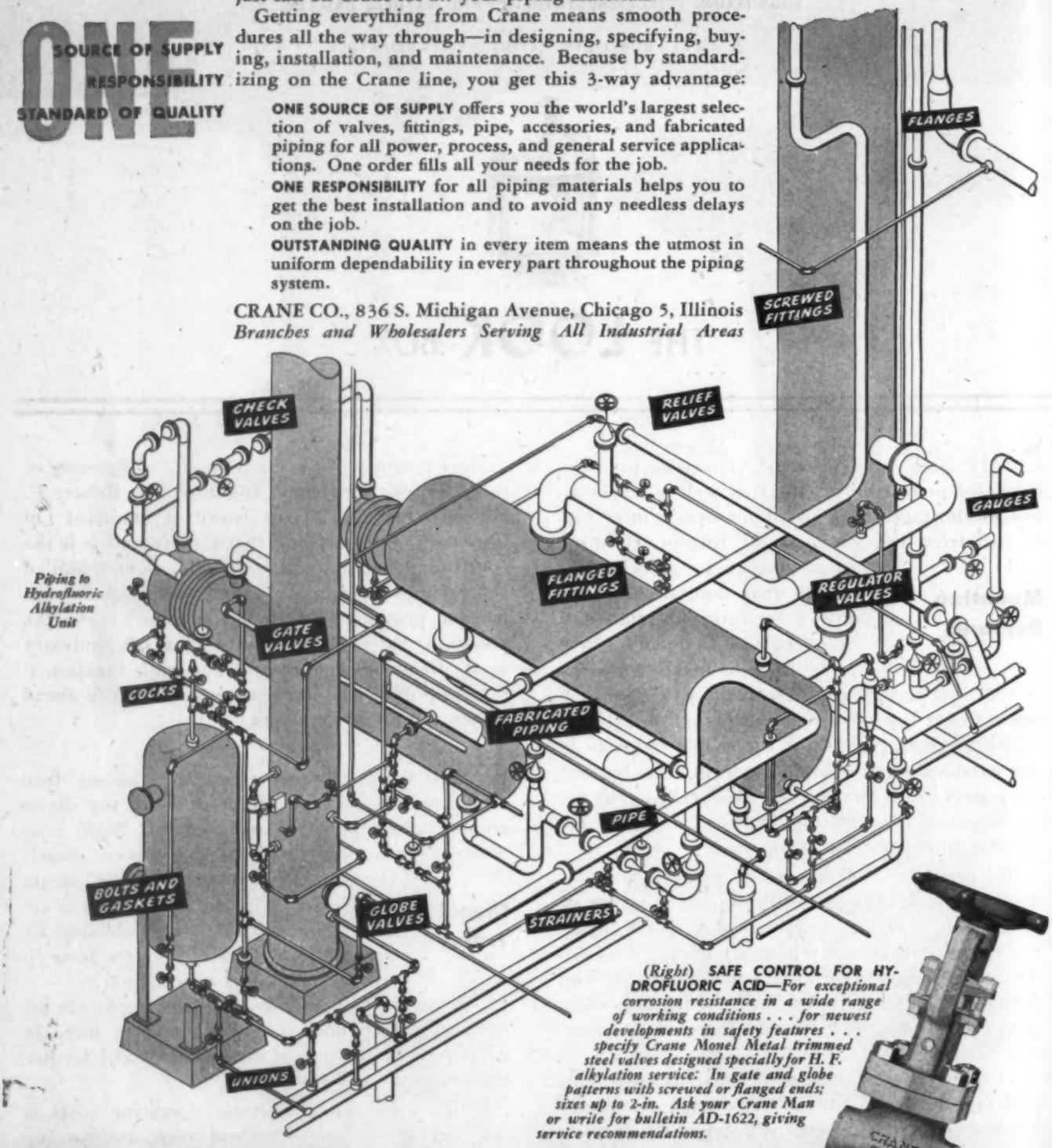

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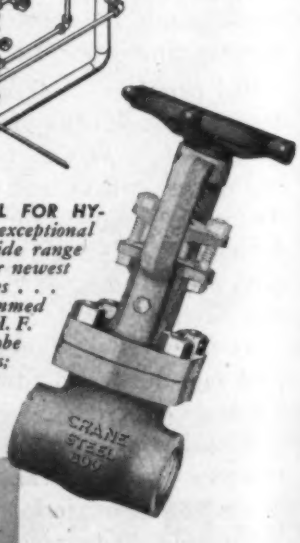

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plants average 25 percent and some reach 30 percent; the gasoline engine 25 percent; while the diesel utilizes a full third, or even slightly more of the heat value in its fuel.

"In actual operation fuel savings are even greater. A steam engine burns fuel as long as there is a fire under its boiler and it may be required to keep steam up while standing idle for long periods. Under such conditions the diesel burns no fuel because its engines can be shut off and restarted when needed."

Two Ways

THE ROLE of atomic energy as a force for good or evil has claimed the imagination of the scientists whose work resulted in the production of the atomic bomb, and with general knowledge of this achievement, of intelligent men everywhere. Forecasts have ranged from promises of Utopia to dire predictions of the end of our civilization. While the benefits to be gained through the constructive application of atomic energy appear to be very great, fear of the further use of this new science as a weapon and of horrible wars of extermination has led to popular comment that the "horse and buggy days" were not so bad, and to the statement by prominent scientists that they are "among the league of frightened men." End results will be revealed by time, but the opinions expressed at a recent API refining division meeting by Arthur Holly Compton, chancellor of Washington University, and one of the leading scientists in the wartime development of the atomic bomb, are along somewhat more hopeful lines and merit careful thought. Compton recounted experimental work in the development of atomic energy, discussed its value as a military weapon, and the prospects for its beneficial use. Quoting directly from this latter portion of his talk:

"Our studies have convinced us that there is no way to protect a city against destruction by such bombs except to insure that they will not be used. I personally see only two methods by which we can get such insurance. The first and most certain is by an agreement in which all parties have confidence that no bombs will be made. This is what the nations are trying to achieve in the discussions now going on in the councils of the United Nations. We earnestly hope that their efforts will be successful. It is not yet evident, however, that such an agreement can be reached. If it cannot, the world will presumably fall back on the second and much less attractive method.

"The second method is for each power that relies on its own strength for defense to prepare itself with atomic bombs and with the means for delivering them effectively on any possible enemy. To avoid the reproach of the world, no nation would start an atomic war except in case of extremity, nor can preparation with atomic weapons insure victory if war should develop. Waging a war to a successful conclusion will require more than atomic bombs. Readiness with such bombs will cause any possible enemy to hesitate long before starting a war, since whether it is victorious or not it will be sure to suffer severe destruction. The reasons for starting a war will accordingly need to be more compelling than those which have brought about any of the wars that have occurred during the last century. This method of protection would have the high cost associated with all competitive armament and would supply a basis for continued international suspicion. It is, however, I believe, the alternative that will be followed if our attempts to reach mutual agreement should fail. With all its difficulties of high cost and continued suspicions, this method would also have the effect of making unlikely the outbreak of war. Before many years have elapsed social forces—will create conditions in which wars between great nations will be almost impossible. Thus we can hope for freedom from war for centuries to come."

Dwindling Resource?

IT IS unfortunate that organizations of the standing of the American Chemical Society are responsible for such descriptions as "America's dwindling resources of cheap lubricants and liquid fuels," part of the opening sentence of a new release concerning the technical documents siezed by the Allied investigators in Germany.

That it will be to the advantage of the economy of this country to take full advantage of what can be learned from German accomplishments in the synthesis of fuels and lubricants from natural gas and water gas is accepted. But to base a plea for this on the false premise that America faces a "dwindling resource of cheap lubricants" seems unjustified. It so happens that production of oil is at an all-time high. Thus far the industry has kept pace with mounting demand, an abnormal demand in war and an unexpected demand since the war. Oil is a growing resource rather than a dwindling resource.

Further in the statement is a quotation from Professor Roger Adams of the University of Illinois:

"We are confronted with an almost certain reduction in our output of petroleum . . . "

On the contrary it seems certain that we are confronted with an almost certain increase in our output of petroleum.

The conviction that our oil reserves are rapidly waning has taken root in many places. Statistics will not support the conviction but it persists and unfortunately too many accept it.

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- EIGHT TURBINE TYPES on five frame sizes.
- EXTREME FLEXIBILITY to meet a wide range of conditions, obtained with standardized modifications.

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Applications of Thermodynamics to Hydrocarbon Processing

Part I

INTRODUCTION AND SUMMARY

WAYNE C. EDMISTER
Hydrocarbon Research, Inc., New York

ALMOST everyone in scientific and industrial circles has at least some knowledge of thermodynamics and its applications. Mathematician, physicist, chemist, steam-power engineer, chemical-process engineer have different but related understandings.

If thoroughly understood and applied with imagination, thermodynamics can be a very useful and powerful tool in process research, development, design, and operation. Although used extensively in the process industries, its powers are not being fully exploited because too few fully appreciate its potentialities and understand the methods of application.

During recent years, thermodynamics has been applied to an ever-increasing number of process problems. Because of the numerous fluids and operations encountered in the process industries, this field of application is almost unlimited. Recent developments in petroleum refining, synthetic rubber, and synthetic chemicals clearly indicate that the chemist and chemical engineer will be dealing with many new constituents and processes in the future. This trend makes the application of thermodynamics even more important.

By means of thermodynamics, it is possible to make the most of research and engineering efforts. The most favorable temperature and pressure conditions for a given chemical reaction and the equilibrium distribution of products may be predicted and thus save considerable laboratory time. Process design calculations can be made by means of phase distribution and heat data correlations and thus avoid excessive pilot-plant development work. Exploratory research and pilot-plant development work are necessary to determine space velocity, catalyst composition, etc., but the proper use of thermodynamics will permit making the most of experimental work.

Types of Applications

There are five types of process applications of thermodynamics, namely: (1) *combustion,* including furnaces and regeneration cycles; (2) *heat balances,* including vaporization, condensation, distillation, and heats of reaction; (3) *power,* including pumping, compression, steam and electric drives, and flue-gas turbines; (4) *phase equilibrium* for ideal and nonideal solutions; and (5) *chemical reaction equilibrium,* involving estimation of equilibrium conditions and yields for reactions.

In general, the same procedure is followed in each of the above groups of applications. First, experimental data are obtained and correlated. Second, tabulations and charts of derived thermodynamic properties are developed. Third, the correlated experimental and derived thermodynamic properties are applied to the problem.

The application of thermodynamics to physical process operations, such as fluid flow, heat transmission, distillation, etc., involves changes in heat or work and phase equilibria for which fugacities, entropies, and enthalpies

THIS article, Part I, introduces a complete series on the applications of thermodynamics in all phases of petroleum processing. In the remaining chapters the author will cover the theory, the mathematical methods, the experimental data required, the development of thermodynamic tools, and the procedure for applying these tools to hydrocarbon processing calculations with many examples.

Chapters for the first 12 articles of this series are:

Part I	Introduction and Summary
Part II	Basic Definitions and Concepts
Part III	Energy and Entropy Functions
Part IV	The Perfect Gas
Part V	Non-Hydrocarbon Fluids
Part VI	Illustrative Problems and Solutions
Part VII	Properties of Hydrocarbons
Part VIII	Generalized Correlations
Part IX	Phase Behavior of Hydrocarbon Mixtures
Part X	Phase Equilibria Estimation Methods
Part XI	Enthalpies and Entropies for Pure Hydrocarbons
Part XII	Enthalpies and Entropies for Hydrocarbon Mixtures

The balance of the series is being prepared. Titles of the remaining articles will be announced when completed.

In the interests of thoroughness, derivations and explanations are included for the equations and many charts are reprinted in this series, even though some of these items may be found in previously published articles and books. This series has been written specially for engineers working in the petroleum and related industries.

The author has published many articles in this field, the first appearing while he was a student at Oklahoma A. & M. College. His industrial experience includes: the design and construction of gas and natural-gasoline plants; the development, design and operation of petroleum-refining processes; and the operation of synthetic-rubber plants. Having worked for Standard Oil Company (Indiana), Rubber Reserve Company and Foster Wheeler Corporation, the author has applied his technology in the refining, government and contracting fields. In addition, he has taught advanced chemical engineering subjects at Illinois Institute of Technology and New York University, and gave instructions in petroleum refining process design at Whiting for Standard Oil Company (Indiana) employes. This series on applications of thermodynamics is in part an outgrowth of the courses given at Chicago, Whiting, and New York.

This Introduction and Summary chapter was presented before the Divisions of Chemical Education and Physical and Inorganic Chemistry of the American Chemical Society at its 108th meeting in New York, September 12, 1944. Later it appeared in the January, 1945, issue of the Journal of Chemical Education under the title, "Applications of Thermodynamics to the Process Industries."

"Hydrocarbon Thermodynamics," presented before the California Natural Gasoline Association on November 1, 1945, was the author's most recent paper on this subject. Reader response inspired the writing of this series.

Note: Correspondence to the author relative to this series should be sent to his home address: 7 Gilmore Court, Scarsdale, New York.

for liquids and vapors, both pure and in mixture are required. The application of thermodynamics to chemical reactions involves the use of free energies for the reactants and the products, for which heats of fusion, vaporization, and formation as well as heat capacities are required.

Fundamentals of Thermodynamics

A thorough working knowledge of the fundamentals of thermodynamics is essential for most applications and desirable for all others. It is easy to lose sight of the fundamentals while working with the details. Six tables

TABLE 1*

Six Mathematic Transformations of Variables for Use in Deriving Thermodynamic Equations

TRANSFORMATION OF VARIABLES						
No.	Variables	From	To	Equation	Variable Exchange	Variable Substitute
1	P,V,T	$\left(\frac{\partial V}{\partial T}\right)_P$	$\left(\frac{\partial T}{\partial V}\right)_P$	$\left(\frac{\partial T}{\partial V}\right)_P = \frac{1}{\left(\partial V/\partial T\right)_P}$	T AND V	
2	P,V,T	$\left(\frac{\partial V}{\partial T}\right)_P$	$\left(\frac{\partial V}{\partial P}\right)_T$	$\left(\frac{\partial V}{\partial P}\right)_T = -\frac{\left(\partial V/\partial T\right)_P}{\left(\partial P/\partial T\right)_V}$	T AND P	
3	P,V,T	$\left(\frac{\partial V}{\partial T}\right)_P$	$\left(\frac{\partial P}{\partial T}\right)_V$	$\left(\frac{\partial P}{\partial T}\right)_V = -\frac{\left(\partial V/\partial T\right)_P}{\left(\partial V/\partial P\right)_T}$	P AND V	
4	P,V,T,S	$\left(\frac{\partial V}{\partial T}\right)_P$	$\left(\frac{\partial V}{\partial S}\right)_P$	$\left(\frac{\partial V}{\partial S}\right)_P = \frac{\left(\partial V/\partial T\right)_P}{\left(\partial S/\partial T\right)_P}$		S FOR T
5	P,V,T,S	$\left(\frac{\partial V}{\partial T}\right)_P$	$\left(\frac{\partial S}{\partial T}\right)_P$	$\left(\frac{\partial S}{\partial T}\right)_P = \frac{\left(\partial V/\partial T\right)_P}{\left(\partial V/\partial S\right)_P}$		S FOR V
6	P,V,T,S	$\left(\frac{\partial V}{\partial T}\right)_P$	$\left(\frac{\partial V}{\partial T}\right)_S$	$\left(\frac{\partial V}{\partial T}\right)_S = \left(\frac{\partial V}{\partial T}\right)_P + \left(\frac{\partial V}{\partial P}\right)_T \left(\frac{\partial P}{\partial T}\right)_S$ OR $\left(\frac{\partial V}{\partial T}\right)_S = \left(\frac{\partial V}{\partial T}\right)_P - \left(\frac{\partial V}{\partial S}\right)_T \left(\frac{\partial S}{\partial T}\right)_V$		S FOR P

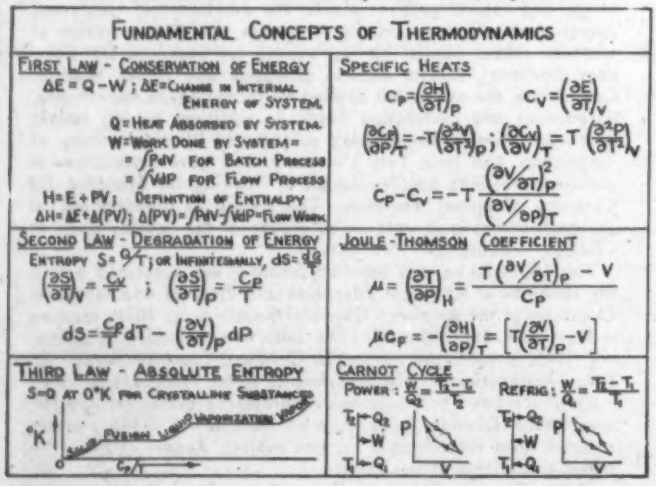
* This table was prepared in 1944 from class notes taken in a Thermodynamics course given by Prof. T. F. Young, University of Chicago, in 1934.

(Tables 1 through 6) have been prepared presenting the fundamentals that constitute the framework of the thermodynamics used in the process industries. The equations shown are all derived by applying mathematics to the fundamental concepts and laws.

Transformation of Variables. The language of thermodynamics is mathematics. In deriving thermodynamic equations, it is frequently necessary to transform variables. Table 1 shows six relations for making these transformations, which are derived by manipulating general differential equations defining the relationship of the variables. From a knowledge of these transformations it is easy to master the derivation of the thermodynamic relationships.

TABLE 2

Fundamental Laws and Concepts of Thermodynamics


FUNDAMENTAL CONCEPTS OF THERMODYNAMICS
FIRST LAW - CONSERVATION OF ENERGY
ΔE = Q - W ; ΔE = CHANGE IN INTERNAL ENERGY OF SYSTEM.
Q = HEAT ABSORBED BY SYSTEM.
W = WORK DONE BY SYSTEM = = ∫PdV FOR BATCH PROCESS = ∫VdP FOR FLOW PROCESS
H = E + PV ; DEFINITION OF ENTHALPY
ΔH = ΔE + Δ(PV) ; Δ(PV) = ∫PdV - ∫VdP = FLOW WORK
SPECIFIC HEATS
SECOND LAW - DEGRADATION OF ENERGY
ENTROPY S = Q/T ; OR INFINITESIMALLY, dS = dQ/T
JOULE-THOMSON COEFFICIENT
THIRD LAW - ABSOLUTE ENTROPY
S = 0 AT 0°K FOR CRYSTALLINE SUBSTANCES
°K
SOLID
EVAPORATION
LIQUID
VAPORIZATION
VAPOR
CARNOT CYCLE
POWER : W/Q2 = (T2 - T1)/T2
REFRIG : W/Q1 = (T2 - T1)/T1
P
V

Laws and Concepts. The fundamental laws and concepts of thermodynamics are summarized in Table 2 where the three laws are defined. The first and second laws together form the foundation for most of the thermodynamics used in the process industries. The concepts of conservation and degradation of energy permit developing many useful equations for thermodynamic properties of fluids and for phase and reaction equilibria. The third law, which enters into the computation of free energies for reactions, has fewer applications than the first two laws.

Entropy, the quantitative measure of the degradation or unavailability of energy is the most frequently misunderstood concept of thermodynamics. The missing link in the understanding of entropy appears to be the significance of the degradation of energy and its relation to the derivation of the various thermodynamic equations.

Considerable confusion exists regarding reversible and irreversible processes and the related significance of entropy. The Carnot cycle is a classic means of explaining reversibility and entropy. Hence, the power and refrigeration Carnot cycles are included in this table of fundamentals. Specific heat and Joule-Thomson relations are also shown to illustrate important fundamental relations derived from the first and second laws.

Thermodynamic Properties

The thermodynamic properties required for the many fluids handled in the process industries include: densities, vapor pressures, critical state, fugacities, entropies, enthalpies, and free energies. Some of these properties must be experimentally determined, while others are computed from basic experimental data by means of thermodynamic equations.

TABLE 3

Definitions and Equations of Four Thermodynamic Potentials

THERMODYNAMIC POTENTIALS					
Potential	Symbol	Mathematical Definitions	Independent Variables	Differential Equations: Basic	Differential Equations: Transformed
Residual Work (Helmholtz Free Energy)	A	A = F - PV A = E - TS	V,T	dA = -PdV - SdT	
Free Energy (Gibbs Free Energy)	F	F = A + PV F = H - TS	P,T	dF = +VdP - SdT	
Internal Energy	E	E = A + TS E = H - PV	V,T	dE = -PdV + TdS	$dE = C_v dT + \left[T\left(\frac{\partial P}{\partial T}\right)_V - P\right]dV$
Enthalpy	H	H = A + TS + PV H = F + TS H = E + PV	P,T	dH = +VdP + TdS	$dH = C_p dT + \left[V - T\left(\frac{\partial V}{\partial T}\right)_P\right]dP$

Thermodynamic Potentials. The four thermodynamic potentials (residual work, free energy, internal energy, and enthalpy) are all related to each other as shown by the definitions in Table 3. These four properties are functions of pressure, temperature, volume, and entropy in a systematic manner. The residual work is useful in deriving phase equilibria relations, as is the free energy, the choice depending upon the type of data forming the basis for the computations. Internal energy and the enthalpy are also important functions, the enthalpy being the most frequently and widely used of all four thermodynamic potentials.

Experimental Data. The following types of experimental data are required for computing thermodynamic properties: (*a*) *volumetric* data, i.e., pressure-volume-temperature measurements, including vapor pressures

and critical data; (*b*) *calorimetric* data, i.e., specific heats, latent heats of fusion and vaporization, heats of combustion and formation; (*c*) *thermal coefficients*, i.e., Joule-Thomson coefficient and the isothermal effect of pressure on the enthalpy; and (*d*) *phase behavior* data, i.e., the amounts and composition of the equilibrium liquid and vapor at various temperatures and pressures. It is important that chemists and chemical engineers working in this field be conversant with previous and current experimental work. Sage and Lacey[12] have made many contributions in this field.

Pressure-volume-temperature data for single component hydrocarbon systems are available in sufficient quantity and quality to permit developing adequate correlations. One technique used in obtaining *P-V-T* data is the calibrated high-pressure glass capillary tube, used by W. B. Kay.[7] Although more single component *P-V-T* data would be of interest, the need for data on mixtures is much more urgent.

With more than one component in the system, The *P-V-T* experimental problem is complicated by the need for composition data on the equilibrium vapor and liquid in the two phase region. *P-V-T* data on binary systems also yield phase equilibria information. For three or more components, this method has limitations because the compositions of equilibrium vapor and liquid cannot be determined.

Specific heats of liquids and vapors as well as the heats of vaporization are required in preparing entropy and enthalpy charts. Spectroscopic methods have been employed extensively in the computation of heat capacities. In this connection, it is felt that there should be more calorimetric data obtained to check the spectroscopic heat capacities. Likewise, more calorimetric data should be obtained to check heats of vaporizations computed from the vapor pressures and the densities of saturated vapor and liquid.

The Joule-Thomson coefficient and the isothermal effect of pressure on the enthalpy may be computed from volumetric data. However, these calculated values should also be checked by experimental data, especially for mixtures. Roebuck[11] has made many contributions of Joule-Thomson coefficient data. Gilliland, et al[5, 6] has experimentally determined the isothermal effect of pressure on some gases.

TABLE 4

Thermodynamic, Graphic, and Analytic Equations of State for Use in Computing Thermodynamic Properties of Fluids

EQUATIONS OF STATE	
THERMODYNAMIC $P = T\left(\frac{\partial P}{\partial T}\right)_V - \left(\frac{\partial E}{\partial V}\right)_T$ $V = T\left(\frac{\partial V}{\partial T}\right)_P + \left(\frac{\partial H}{\partial P}\right)_T$	BEATTIE-BRIDGEMAN $P = \frac{RT(1-c/VT^3)}{V^2}\left[V+B_o(1-b/V)\right] - \frac{A_o}{V^2}(1-a/V)$ OR $P = RTd + (B_oRT - A_o - Rc/T^2)d^2 + (-B_obRT + A_oa - B_oRc/T^2)d^3 + B_oRbcd^6/T^2$
VAN DER WAALS $P = \frac{RT}{V-b} - \frac{a}{V^2}$ OR $P = \frac{RTd}{1-bd} - ad^2$	BENEDICT ET AL $P = RTd + (B_oRT - A_o - C_o/T^2)d^2 + (bRT - a)d^3 + a\alpha d^6 + \frac{cd^3(1-\gamma d^2)\exp(-\gamma d^2)}{T^2}$ CONSTANTS FOR MIXTURES $A_o = [\Sigma x_i (A_{oi})^{1/2}]^2$ $a = [\Sigma x_i (a_i)^{1/3}]^3$ $B_o = \Sigma x_i B_{oi}$ $b = [\Sigma x_i (b_i)^{1/3}]^3$ $C_o = [\Sigma x_i (C_{oi})^{1/2}]^2$ $c = [\Sigma x_i (c_i)^{1/3}]^3$ $\alpha = [\Sigma x_i (\alpha_i)^{1/3}]^3$ $\gamma = [\Sigma x_i (\gamma_i)^{1/2}]^2$
GRAPHICAL VOLUME RESIDUALS $\alpha = \frac{RT}{P} - V$ $\Delta = V\left(\frac{PV}{RT} - 1\right)$ PLOT α AND Δ VS P AND T COMPRESSIBILITY FACTOR $Z = PV/RT$ PLOT Z VS P_R AND T_R	

Equations of State. Graphical and analytical methods are used in correlating *P-V-T* data for hydrocarbons. Table 4 presents several equations of state. The graphical methods have been used more extensively than the others. In the graphical methods the *P-V-T* data for pure hydrocarbons are correlated by means of the theorem of corresponding states by using reduced conditions, i.e., ratios of the actual values of pressure, temperature, etc., to the values at the critical state. One technique employed in computing thermodynamic properties of hydrocarbons graphically is to use the volume residuals, i.e., difference between the perfect gas and the actual volumes. By means of volume residuals, the derivatives of the volume may be evaluated accurately by graphical methods.

The *P-V-T* data for mixtures may be correlated on the same graph with pure components by using the pesudocritical state in computing the reduced conditions for the mixture, estimating the pseudocritical for the mixture from the true criticals of the components. The pseudocritical concept, a contribution of W. B. Kay[7] and a very useful chemical engineering tool, is adequate for estimating densities and changes in enthalpies for hydrocarbon mixtures. Although valuable in these respects, the pseudocritical concept is too approximate for use in developing phase equilibria relationships for mixtures in the higher pressure ranges where the laws of ideal solutions do not apply.

With reference to the use of reduced states in correlating density data, K. M. Watson[14] recently published a correlation of this kind for liquid densities that is of interest and value to chemical engineers.

The equation of state developed by Benedict et al[1] forms the basis for deriving accurate relations for computing densities, entropies, enthalpies, free energies, and fugacities for single and multicomponent systems. This equation of state is the most versatile known to the writer. It will be noted that the Benedict equation of state is explicit in pressure, which makes it difficult to obtain volume derivatives. However, this disadvantage is offset by the fact that this equation applies to both liquid and vapor phases. This is not possible in an equation explicit in volume.

The constants for the Benedict equation are evaluated from experimental data, such as vapor pressures, densities, critical conditions, heats of vaporization, etc., for pure hydrocarbons, and then computing the constants for mixtures from the constants for the individual components by the relations shown in Table 4. This equation is particularly useful in preparing tables and charts of thermodynamic properties for use in making routine process calculations. It is not well adapted for direct use in making these routine calculations, however, because of its complexity. This indirect application to the development of tables and charts of thermodynamic properties is one of the most important applications of thermodynamics in the process industry.

Phase Equilibrium. For some mixtures, and temperature-pressure conditions, the vapor pressures and the total pressures may be used in making phase equilibrium calculations. In these cases only vapor-pressure correlations are required. For other situations where vapor pressures cannot be used but the liquid and vapor phases are ideal solutions, "ideal fugacities" or "corrected vapor pressures" may be used in phase-equilibrium calculations. These fugacity-equilibrium constants are obtained from the *P-V-T* data for the pure components, by means of graphical or analytical equations of state. At higher pressures, i.e., near the critical, the liquid and vapor phases are nonideal so the problem becomes much more complicated.

Table 5 shows the important features of the thermodynamics relating to these three methods of making

phase-equilibria calculations. This table shows the equations for the vapor pressure and ideal fugacity phase distribution constants, which are straightforward and require no further explanation. The situation regarding non-ideal solutions, on the other hand, is quite different. Several empirical and theoretical attacks have been made on this type of equilibrium problem.

From a theoretical standpoint, separate correlations

TABLE 5

Phase-Equilibrium Relationships for Ideal and Nonideal Solutions

PHASE EQUILIBRIUM

VAPOR PRESSURE RELATIONSHIP

Combining Dalton's Law, $p = Py$ and Raoult's Law, $p = \Pi x$ Gives

$p = \Pi x = Py$ — Valid only at Low Pressures for Ideal Solutions

$K = \frac{y}{x} = \frac{\Pi}{p}$

K = Equil. Phase Distribution Const.

x, y = Mol Fract. in Liq. & Vap.

p, Π, P = Partial, Vapor and Total Pressures

FUGACITY - ESCAPING TENDENCY

For Perfect Gas

$\Delta F_T = RT \ln P_2/P_1$

For Actual Gas

$\Delta F_T = RT \ln f_2/f_1$

Where f is the Fugacity, which is Defined to Replace Pressure, From which

$RT \ln \frac{f}{p} = -\int_0^P \alpha dP$

Where $\alpha = V - \frac{RT}{P}$

FUGACITY EQUILIBRIUM RELATIONSHIPS

Ideal Solutions - Fugacity of each component is proportional to its mol fraction at every temperature & pressure

$f_l x = f_v y$

$K = \frac{y}{x} = \frac{f_l}{f_v} = \left(\frac{f_l/p}{f_v/p}\right)\frac{\Pi}{P}$

$f_l = f_p$ = fugacity of pure component in liquid phase or at the vapor pressure, Π.

$f_v = f_p$ = fugacity of pure component in vapor phase or at the total pressure, P.

Non-Ideal Solutions - Fugacities of components in both liquid and vapor phases are functions of temp., press., and phase compositions

1. Phase Diagram Method
2. Equil. Bomb Method
3. Convergence Pressure
4. Equation of State Method

of the fugacities for the liquid and vapor phases (as functions of temperature, pressure, and phase composition) would be desirable, provided the correlations were not too complex. Such fugacities could be computed with relations derived from the Benedict equation of state. The preparation and application of such data are a laborious procedure, however. Experimental phase-equilibrium data should be used to supplement the equation of state calculations.

An empirical method, employing the convergence pressure concept, has been proposed by G. G. Brown. This method, which is discussed in an article by White and Brown,[15] is based on the fact that on an equilibrium constant versus pressure plot for a given constant temperature the lines for different hydrocarbons converge at a high pressure, which is the critical pressure when the temperature is the critical temperature. Experimental data are required on many mixtures to develop this method, which should prove to be adequate for most ordinary problems and also simpler than the separate fugacity method.

The experimental phase-equilibria data required in developing the separate fugacity and the convergence pressure correlations may be obtained by determinations of batch or flow phase equilibria. The high pressure calibrated glass tube used by Kay[2, 7] is an example of the batch technique. This method is very good for determining border curves and the relative amounts of liquid and vapor. The compositions of the equilibrium vapor and liquid cannot be found with this method. For binary systems, the equilibrium constants may be computed from these border curves.

For more than two components the equilibrium bomb may be used. In this method, samples of the equilibrium vapor and liquid may be removed for analysis by displacing the volume of the samples with mercury to maintain equilibrium. Another method employed with success by Gilliland[6] is the equilibrium still method, which may be called semi-continuous. Continuous phase-equilibria determinations have been made in two types of equipment, as illustrated by White and Brown[15] and by this author.[4]

For some multicomponent higher-boiling petroleum fractions, such as gasoline, the component technique of making phase-equilibria calculations is not practical because of the large number of components. For mixtures of this type, it is necessary to use empirical methods based on laboratory distillations to construct the phase diagram, from which the boiling points, dew points, and relative amounts of liquid and vapor may be obtained. Likewise, empirical correlations can be derived to estimate the composition of the equilibrium vapor and liquid.

Phase diagrams for three petroleum fractions were published recently[4] from data obtained by continuous equilibrium flash vaporization runs at different temperatures and pressures. It is of interest to note that the lines of constant percent vaporized are straight lines on log of the pressure to the base 10 vs reciprocal of absolute temperature. The lower portions of these lines can be predicted by ideal fugacities.

Entropies and Enthalpies. The preparation and the application of entropy and enthalpy charts and tabulations for pure fluids and their mixtures represent one of the most important applications of thermodynamics. In computing entropies and enthalpies for these charts and tables, it is customary to correlate, smooth, interpolate, and extrapolate the experimental vapor pressure, heat capacity, latent heat, and volumetric data by graphical or analytical methods.

The isobaric effects of temperature on the entropy or the enthalpy are computed from the heat capacity, while the isothermal effect of pressure may be computed from volumetric data by means of thermodynamic equations. As indicated above, it is desirable but not always necessary to have experimental data on the effect of pressure also. Graphical methods using residual volumes have been applied to pure components by several workers[3, 16, 18] in this field. This method may also be applied to mixtures by means of the pseudocritical concept.

Another method that has been applied to single and multicomponent systems is the equation of state of Benedict. This method is more tedious than the pseudocritical technique for mixtures but on the other hand is theoretically sounder.

Enthalpy vs temperature charts for the lighter hydrocarbons can be prepared from existing data. These charts can be applied to mixtures by assuming that the enthalpies are additive. The accuracy of heat balances made by the writer on light hydrocarbon process equipment indicates that the assumption of additivity is justified for these hydrocarbons at moderate pressures.

Mollier diagrams, i.e., charts involving entropy and enthalpy for light hydrocarbons and some of their mixtures, have been prepared and published.[8] These charts were prepared by the graphical method, assuming additivity for the mixtures, and then spot checked by means of the more sound equation-of-state method. The two methods were found to be in satisfactory agreement at the points checked. Charts of this kind are useful in making refrigeration calculations, which often arise in the process industries. Hydrocarbons, both pure and in mixtures, frequently are used as refrigerants. In this connection, the method of York[17] for making compression calculations is useful where it is not practical to prepare Mollier diagrams for the fluid in advance.

Enthalpy vs temperature charts for higher-boiling petroleum fractions, such as gasoline, etc., can be prepared by using the pseudocritical technique with graphically integrated volumetric derivatives. On charts of this

kind the constant pressure lines slope in the two-phase region, representing the change in temperature between the boiling and dew lines, which bound the two-phase region forming the phase diagram. Thus charts of this kind are a combination phase and enthalpy diagram and very valuable in making computations for the mixture. For example, the final temperature after throttling at constant enthalpy into or out of the two-phase region may be found from this chart.

TABLE 6
Equation for the Application of Thermodynamics to Chemical Reactions

CHEMICAL REACTION EQUILIBRIUM

HEAT OF REACTION

$\left(\frac{\partial \Delta H}{\partial T}\right)_p = \Delta C_p$ FROM WHICH

$\Delta H_2 - \Delta H_1 = \int_1^2 \Delta C_p dT$

$C_p = A + BT + CT^2$; FOR EACH COMPONENT. ADDING CONSTANTS A,B,C ALGEBRAICALLY GIVES $\Delta C_p = \Delta A + \Delta BT + \Delta CT^2$ FOR MIXTURE. SUBSTITUTING AND INTEGRATING $\Delta H = \Delta H_2 + \Delta AT + \frac{1}{2}\Delta BT^2 + \frac{1}{3}\Delta CT^3$

FREE ENERGY OF REACTION

$\frac{d\left(\frac{\Delta F}{T}\right)}{dT} = -\frac{\Delta H}{T^2}$

$\Delta F = \Delta H_1 - \Delta AT \ln T - \frac{1}{2}\Delta BT^2 - \frac{1}{6}\Delta CT^3 + IT$

INTEGRATION CONSTANT I EVALUATED FROM ΔF AT KNOWN TEMPERATURE AND ΔS FROM THIRD LAW AND FOLLOWING EQUATION $\Delta F = \Delta H - T\Delta S$

EQUILIBRIUM YIELDS

EQUILIBRIUM CONSTANT FROM ΔF

$\Delta F = -RT \ln K_f$

LAW OF MASS ACTION

$aA + bB = cC + dD$

$K_p = \frac{(\text{Conc } C)^c (\text{Conc } D)^d}{(\text{Conc } A)^a (\text{Conc } B)^b}$

FOR VAPOR PHASE REACTIONS PARTIAL PRESSURES AND ACTIVITY COEFFICIENTS MAY BE USED AS FOLLOWS

$K_p = \frac{K_f}{K_\gamma} = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$

$K_\gamma = \frac{(\gamma_C)^c (\gamma_D)^d}{(\gamma_A)^a (\gamma_B)^b}$

DATA REQUIRED

1. HEAT CAPACITIES
2. HEATS OF FORMATION
3. ABSOLUTE ENTROPIES
4. VAPOR PRESSURES AND FUGACITIES

Chemical Reaction Equilibrium. Thermodynamics may be used to estimate the equilibrium of a given reaction and thus predict the conditions most favorable to it. By a combination of thermodynamics and kinetics, the equilibrium distribution of products may be estimated. The heat absorbed or liberated in a reaction may also be found by means of equations derived by thermodynamics. The fundamental equations for these computations are given in Table 6.

Experience at many research laboratories has proved the value of compiling tabulations and charts giving thermodynamic data for the formation of various compounds of interest to that organization. For example, petroleum research laboratories have done this for the heats and free energies of formation for the hydrocarbons. These data are computed from heats of formation and entropies, the latter being prepared by means of the third law and low-temperature heat capacities together with heats of vaporization and fusion. Heats and free energies for reactions are found by combining the heats and free energies of formation for the reactants and products.

Although thermodynamics is very useful in studying chemical reactions, it does not give any clue to the approach to equilibrium. For this, supplementary data on heat transfer rates, diffusion coefficients, rates of mixing, viscosities, and reaction velocities are required. Exploratory research and pilot-plant development work are necessary to obtain this supplementary information.

Process Applications

Practically all industrial processes involve the conversion of energy from one form to another and of course some energy is always lost to the low-temperature heat "sink," which may be the flue gas stack, the cooling, water, etc.

Unit Operations. In the design and operation of chemical processes, the chemical engineer is concerned with the unit operations, namely: fluid flow, heat transfer, vaporization and condensation, absorption and stripping, distillation and extraction, combustion and catalyst regeneration, etc. In all of these unit operations, thermodynamics is a useful tool. In the flow of fluids, various forms of energy are involved. In the transfer of heat, enthalpy is the contribution of thermodynamics. For the separation processes, phase-equilibria and enthalpy data are required in making the various design calculations and analyzing plant performance.

Where there are substantial variations in the molal overflow in distillation and extraction operations it is necessary to make heat-balance calculations at frequent intervals. For these calculations constant pressure plots of enthalpy vs compositions with constant temperature tie-lines are sometimes helpful. Recent articles by Randall and Longtin[10] and an earlier one by Thiele[18] deal with this technique.

In most processes, preheating and vaporization furnaces are required to prepare the fluid for reaction. The design of these furnaces usually is more complicated than the design of steam boilers because of the type of fluid being handled, it being necessary to consider the time-temperature gradient for the fluid in order to avoid overheating and thermal decomposition. The combustion and flue-gas calculations, which are no different from those for steam boilers, require heats of combustion and specific heats of the combustion products. In many process furnaces, flue gases are recirculated to avoid overheating and at the same time keep the economy as high as possible.

There are a number of other operations where flue-gas calculations must be made, namely, catalyst-regeneration cycles, waste-heat boilers, and flue-gas turbines. For these calculations it is necessary to have tables and charts of volumes, entropies, and enthalpies, as functions of pressure, temperature, and composition, as defined by hydrogen/carbon ratio of the fuel and excess oxygen.

Process Operations. Thermodynamics plays an important role in the design and operation of commercial processes. Recent process developments in the petroleum industry have resulted in great progress along synthetic lines. In addition to motor fuel and lubricants, special hydrocarbons are now being manufactured for inclusion in aviation gasoline and for the manufacture of explosives. In addition, various alcohols and raw material for manufacture of synthetic rubber and plastics are prepared from petroleum hydrocarbons. A recent article by Murphree[9] describes many new developments in the petroleum industry.

Many chemical processes are in operation and others are being developed to manufacture products essential to war and peace activities from different starting raw materials, such as: natural gas, refinery gases, casinghead gasoline, petroleum, coal, shale, salt, corn, wheat, corn cobs, rice hulls, sawdust, etc. All of these processes have many similarities. Regardless of future developments, the process industries will still be concerned with the same fundamentals and unit operations. Without going into detail, a few of the thermodynamic applications will be discussed.

The recent development and commercialization of the fluid-catalyst cracking process has started a new trend in catalysis. In this process fine-mesh catalyst is fluidized by steam, air, or hydrocarbon vapors and circulated through the reaction and regeneration stages of the process. This principle has been applied to the cracking of petroleum to produce high-octane aviation gasoline.

In the future it will undoubtedly be applied to other process operations as well. The fluidized catalyst presents many problems, some of which can be solved by the use of thermodynamics. Although the fluid catalyst principle is new, its application involves the use of various well-known unit operations, such as heat transfer, distillation, etc., to prepare the feed stock and handle the products from the reaction.

In contrast to the fluid process there are many new processes in operation employing a stationary catalyst bed with intermittent reaction and regeneration. An example of this type of process in the petroleum industry is the hydroforming process for the manufacture of aromatics. In the commercial version of this process, there are usually two sets of reactors so that one is reacting while the other one is being regenerated. The regeneration of the catalyst is accomplished by the circulation of flue gas containing oxygen, the amount of oxygen being regulated to permit regeneration without overheating the catalyst. The heat liberated by burning the catalyst deposit is removed in waste-heat boilers generating steam, the excess flue gas produced being removed from the system by venting the gases to the atmosphere through a flue gas turbine generating by-product power to compress the flue gases and the air.

Another example of the intermittent catalytic process is the Houdry process, where oil is cracked in stationary catalyst beds that are also regenerated intermittently. The gas from regeneration of the catalyst is likewise expanded through a flue-gas turbine, thus generating power for the compression of air for regeneration. In this process the temperatures in the reaction and regeneration zones are controlled by means of a circulating molten salt, which carries heat from a regenerating to a reacting catalyst bed.

A very important consideration in the design and operation of every process is the over-all heat balance, *i. e.*, the balance between the various power and heating loads. Power for pumping and compressing might be supplied by electricity, steam, or gas engines. Process and building heats usually are supplied by steam at different pressures, depending upon the duty. It is important that this balance be worked out for greatest economy through all seasons of the year. If there are uncertainties in the process-heating and power requirements, the utilities may not be properly designed, with the result that it may be necessary to blow steam to the atmosphere in the summer or reduce excessive amounts of high pressure steam in the winter to maintain a heat balance on the operation. Accurate thermodynamic properties of the fluids being processed are obviously important for calculation of over-all heat balances.

Conclusions

In conclusion, the science and art of mastering and applying thermodynamics may be divided into the following steps: (1) mathematics; (2) concepts and theories; (3) derived thermodynamic equations; (4) fundamental volumetric and calorimetric data; (5) correlation of data and development of tables and charts of thermodynamic properties; and (6) the application of the above to the problem.

It is important that the chemist and chemical engineer have a thorough understanding and familiarity with the mathematics, laws, and formulations of thermodynamics and that they appreciate but do not over-rate its potentialities. In addition, they should have imagination and curiosity regarding the application of thermodynamics to industrial problems and be conversant with the developments and writings of previous and contemporary workers in this field. As in any other subject, it is of value to be able to discuss thermodynamics intelligently with industrial executives.

Chemists and chemical engineers preparing for work in the process industries should receive a sound and inspirational training in thermodynamics and its past, present, and potential applications.

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(To Be Continued)

Curve Fitting And Surface Fitting

Method of Least Squares

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I. Introduction

INTEREST has been shown in curve fitting and surface fitting using the method of least squares. Curve fitting and surface fitting appear to be particularly convenient in the correlation of plant data. In the plant an investigator usually encounters a number of variables, and during an investigation it is difficult to control all variables except the one being studied. Fitting an equation to plant data sometimes constitutes a convenient method of analyzing plant operations.

There are many texts on the subject of least squares, but usually these texts are not concerned with the presentation of the specific determinants used in curve fitting and surface fitting. It appears helpful for engineers to have a catalog of these determinants, and it is the purpose of this report to present a small catalog of determinants.

II. Theory

The principle underlying the method of least squares is this: the best curve or surface of a given type through a set of data is that curve or surface in which the sum of the squares of the deviations of the experimental points from the smoothed curve or surface is a minimum. As is done in most cases, the material presented herein concerns those situations in which the major experimental errors occur in connection with only one of the variables. A similar presentation can be developed for situations wherein major experimental errors occur in more than one of the variables. However, a consideration of the latter is beyond the scope of this paper. Attention is directed to the fact that only those equations are considered in which one variable is an explicit function of the other variables.

Assume that the data

$x_1y_1z_1$, $x_2y_2z_2$, $x_3y_3z_3$, $x_4y_4z_4$, etc.,

are described best by the relationship,

$$z = A\,x + B\,y + C \tag{1}$$

Also assume that the major experimental errors occur in the observed values of z and that the errors in the observed values of x and y are negligible. The determination of constants A, B and C is developed below.

Based on the principle of least squares:

$$z_1-(Ax_1+By_1+C)]^2+[z_2-(Ax_2+By_2+C)]^2+[z_3-(Ax_3+By_3+C)]^2+\ldots\ldots = \text{minimum} \tag{2}$$

Consequently,

$$\frac{\delta}{\delta A}\Sigma\,[z_i-(Ax_i+By_i+C)]^2=0 \tag{3}$$

$$\frac{\delta}{\delta B}\Sigma\,[z_i-(Ax_i+By_i+C)]^2=0 \tag{4}$$

$$\frac{\delta}{\delta C}\Sigma\,[z_i-(Ax_i+By_i+C)]^2=0 \tag{5}$$

The partial differentials of Equation 2 are:

$$\frac{\delta}{\delta A}=2[z_1-(Ax_1+By_1+C)](-x_1)+2[z_2-(Ax_2+By_2+C)](-x_2)+2[z_3-(Ax_3+By_3+C)](-x_3)+\ldots=0 \tag{6}$$

$$\frac{\delta}{\delta B}=2[z_1-(Ax_1+By_1+C)](-y_1)+2[z_2-(Ax_2+By_2+C)](-y_2)+2[z_3-(Ax_3+By_3+C)](-y_3)+\ldots=0 \tag{7}$$

$$\frac{\delta}{\delta C}=2[z_1-(Ax_1+By_1+C)](-1)+2[z_2-(Ax_2+By_2+C)](-1)+2[z_3-(Ax_3+By_3+C)](-1)+\ldots=0 \tag{8}$$

Summation of the corresponding terms in Equations 6, 7 and 8 results in Equations 9, 10 and 11.

$$\Sigma z_ix_i=A\,\Sigma x_i^2+B\,\Sigma y_ix_i+C\,\Sigma x_i \tag{9}$$

$$\Sigma z_iy_i=A\,\Sigma x_iy_i+B\,\Sigma y_i^2+C\,\Sigma y_i \tag{10}$$

$$\Sigma z_i=A\,\Sigma x_i+B\,\Sigma y_i+CN \tag{11}$$

After substituting numerical values for the summations of the terms involving the variables, the simultaneous equations are solved to determine the best values for constants A, B and C. The solution of the simultaneous equations can be made using the determinants given as Equations 12, 13 and 14.

Note: N = number of experimental determinations.

$$A=\frac{\begin{vmatrix}\Sigma z_ix_i & \Sigma y_ix_i & \Sigma x_i\\ \Sigma z_iy_i & \Sigma y_i^2 & \Sigma y_i\\ \Sigma z_i & \Sigma y_i & N\end{vmatrix}}{\begin{vmatrix}\Sigma x_i^2 & \Sigma y_ix_i & \Sigma x_i\\ \Sigma y_ix_i & \Sigma y_i^2 & \Sigma y_i\\ \Sigma x_i & \Sigma y_i & N\end{vmatrix}} \tag{12}$$

$$B=\frac{\begin{vmatrix}\Sigma x_i^2 & \Sigma z_ix_i & \Sigma x_i\\ \Sigma x_iy_i & \Sigma z_iy_i & \Sigma y_i\\ \Sigma x_i & \Sigma z_i & N\end{vmatrix}}{\begin{vmatrix}\Sigma x_i^2 & \Sigma y_ix_i & \Sigma x_i\\ \Sigma x_iy_i & \Sigma y_i^2 & \Sigma y_i\\ \Sigma x_i & \Sigma y_i & N\end{vmatrix}} \tag{13}$$

$$C=\frac{\begin{vmatrix}\Sigma x_i^2 & \Sigma y_ix_i & \Sigma z_ix_i\\ \Sigma x_iy_i & \Sigma y_i^2 & \Sigma z_iy_i\\ \Sigma x_i & \Sigma y_i & \Sigma z_i\end{vmatrix}}{\begin{vmatrix}\Sigma x_i^2 & \Sigma y_ix_i & \Sigma x_i\\ \Sigma x_iy_i & \Sigma y_i^2 & \Sigma y_i\\ \Sigma x_i & \Sigma y_i & N\end{vmatrix}} \tag{14}$$

If there is some theoretical reason for a function to be a certain type, the problem is simply that of determining the constants of the function. However, if

the type of the equation is not known, several functions should be tried.

III. Catalog of Determinants

1. $y = mx + b$

$$m = \frac{\begin{vmatrix} \Sigma y & N \\ \Sigma xy & \Sigma x \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} \quad (15) \qquad b = \frac{\begin{vmatrix} \Sigma x & \Sigma y \\ \Sigma x^2 & \Sigma xy \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} \quad (16)$$

2. $y = Ae^{mx}$ (or) $\ln y = \ln A + mx$

$$m = \frac{\begin{vmatrix} \Sigma \ln y & N \\ \Sigma x \ln y & \Sigma x \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} \quad (17) \qquad \ln A = \frac{\begin{vmatrix} \Sigma x & \Sigma \ln y \\ \Sigma x^2 & \Sigma x \ln y \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} \quad (18)$$

Note: N = number of experimental determinations

The determinants serving as the denominators for each set are identical and are called the principal determinants.

The subscript "i" in the general terms, x_i, y_i and z_i, has been omitted in Section III to simplify the presentation.

3. $y = Ax^2 + Bx + C$

$$A = \frac{\begin{vmatrix} \Sigma y & \Sigma x & N \\ \Sigma xy & \Sigma x^2 & \Sigma x \\ \Sigma x^2 y & \Sigma x^3 & \Sigma x^2 \end{vmatrix}}{\begin{vmatrix} \Sigma x^2 & \Sigma x & N \\ \Sigma x^3 & \Sigma x^2 & \Sigma x \\ \Sigma x^4 & \Sigma x^3 & \Sigma x^2 \end{vmatrix}} \quad (19)$$

$$B = \frac{\begin{vmatrix} \Sigma x^2 & \Sigma y & N \\ \Sigma x^3 & \Sigma xy & \Sigma x \\ \Sigma x^4 & \Sigma x^2 y & \Sigma x^2 \end{vmatrix}}{\begin{vmatrix} \Sigma x^2 & \Sigma x & N \\ \Sigma x^3 & \Sigma x^2 & \Sigma x \\ \Sigma x^4 & \Sigma x^3 & \Sigma x^2 \end{vmatrix}} \quad (20)$$

$$C = \frac{\begin{vmatrix} \Sigma x^2 & \Sigma x & \Sigma y \\ \Sigma x^3 & \Sigma x^2 & \Sigma xy \\ \Sigma x^4 & \Sigma x^3 & \Sigma x^2 y \end{vmatrix}}{\begin{vmatrix} \Sigma x^2 & \Sigma x & N \\ \Sigma x^3 & \Sigma x^2 & \Sigma x \\ \Sigma x^4 & \Sigma x^3 & \Sigma x^2 \end{vmatrix}} \quad (21)$$

4. $z = Ax + By + C$

$$A = \frac{\begin{vmatrix} \Sigma zx & \Sigma yx & \Sigma x \\ \Sigma zy & \Sigma y^2 & \Sigma y \\ \Sigma z & \Sigma y & N \end{vmatrix}}{\begin{vmatrix} \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma x & \Sigma y & N \end{vmatrix}} \quad (12)$$

$$B = \frac{\begin{vmatrix} \Sigma x^2 & \Sigma zx & \Sigma x \\ \Sigma xy & \Sigma zy & \Sigma y \\ \Sigma x & \Sigma z & N \end{vmatrix}}{\begin{vmatrix} \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma x & \Sigma y & N \end{vmatrix}} \quad (13)$$

$$C = \frac{\begin{vmatrix} \Sigma x^2 & \Sigma xy & \Sigma zx \\ \Sigma xy & \Sigma y^2 & \Sigma zy \\ \Sigma x & \Sigma y & \Sigma z \end{vmatrix}}{\begin{vmatrix} \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma x & \Sigma y & N \end{vmatrix}} \quad (14)$$

5. $z = Ax^2 + By^2 + Cxy + Dx + Ey + F$

$$A = \frac{\begin{vmatrix} \Sigma zx^2 & \Sigma y^2x^2 & \Sigma x^2y & \Sigma x^3 & \Sigma yx^2 & \Sigma x^2 \\ \Sigma zy^2 & \Sigma y^4 & \Sigma xy^3 & \Sigma xy^2 & \Sigma y^3 & \Sigma y^2 \\ \Sigma zxy & \Sigma y^3x & \Sigma x^2y^2 & \Sigma x^2y & \Sigma y^2x & \Sigma xy \\ \Sigma zx & \Sigma y^2x & \Sigma x^2y & \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma zy & \Sigma y^3 & \Sigma xy^2 & \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma z & \Sigma y^2 & \Sigma xy & \Sigma x & \Sigma y & N \end{vmatrix}}{\begin{vmatrix} \Sigma x^4 & \Sigma y^2x^2 & \Sigma x^2y & \Sigma x^3 & \Sigma yx^2 & \Sigma x^2 \\ \Sigma x^2y^2 & \Sigma y^4 & \Sigma xy^3 & \Sigma xy^2 & \Sigma y^3 & \Sigma y^2 \\ \Sigma x^2y & \Sigma y^3x & \Sigma x^2y^2 & \Sigma x^2y & \Sigma y^2x & \Sigma xy \\ \Sigma x^3 & \Sigma y^2x & \Sigma x^2y & \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma x^2y & \Sigma y^3 & \Sigma xy^2 & \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma x^2 & \Sigma y^2 & \Sigma xy & \Sigma x & \Sigma y & N \end{vmatrix}} \quad (22)$$

$$B = \frac{\begin{vmatrix} \Sigma x^4 & \Sigma zx^2 & \Sigma x^2y & \Sigma x^3 & \Sigma yx^2 & \Sigma x^2 \\ \Sigma x^2y^2 & \Sigma zy^2 & \Sigma xy^3 & \Sigma xy^2 & \Sigma y^3 & \Sigma y^2 \\ \Sigma x^2y & \Sigma zxy & \Sigma x^2y^2 & \Sigma x^2y & \Sigma y^2x & \Sigma xy \\ \Sigma x^3 & \Sigma zx & \Sigma x^2y & \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma x^2y & \Sigma zy & \Sigma xy^2 & \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma x^2 & \Sigma z & \Sigma xy & \Sigma x & \Sigma y & N \end{vmatrix}}{\text{Principal Determinant}} \quad (23)$$

$$C = \frac{\begin{vmatrix} \Sigma x^4 & \Sigma y^2x^2 & \Sigma zx^2 & \Sigma x^3 & \Sigma yx^2 & \Sigma x^2 \\ \Sigma x^2y^2 & \Sigma y^4 & \Sigma zy^2 & \Sigma xy^2 & \Sigma y^3 & \Sigma y^2 \\ \Sigma x^2y & \Sigma y^3x & \Sigma zxy & \Sigma x^2y & \Sigma y^2x & \Sigma xy \\ \Sigma x^3 & \Sigma y^2x & \Sigma zx & \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma x^2y & \Sigma y^3 & \Sigma zy & \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma x^2 & \Sigma y^2 & \Sigma z & \Sigma x & \Sigma y & N \end{vmatrix}}{\text{Principal Determinant}} \quad (24)$$

$$D = \frac{\begin{vmatrix} \Sigma x^4 & \Sigma y^2x^2 & \Sigma x^3y & \Sigma zx^2 & \Sigma yx^2 & \Sigma x^2 \\ \Sigma x^2y^2 & \Sigma y^4 & \Sigma xy^3 & \Sigma zy^2 & \Sigma y^3 & \Sigma y^2 \\ \Sigma x^3y & \Sigma y^3x & \Sigma x^2y^2 & \Sigma zxy & \Sigma y^2x & \Sigma xy \\ \Sigma x^3 & \Sigma y^2x & \Sigma x^2y & \Sigma zx & \Sigma yx & \Sigma x \\ \Sigma x^2y & \Sigma y^3 & \Sigma xy^2 & \Sigma zy & \Sigma y^2 & \Sigma y \\ \Sigma x^2 & \Sigma y^2 & \Sigma xy & \Sigma z & \Sigma y & N \end{vmatrix}}{\text{Principal Determinant}} \quad (25)$$

$$E = \frac{\begin{vmatrix} \Sigma x^4 & \Sigma y^2x^2 & \Sigma x^3y & \Sigma x^3 & \Sigma zx^2 & \Sigma x^2 \\ \Sigma x^2y^2 & \Sigma y^4 & \Sigma xy^3 & \Sigma xy^2 & \Sigma zy^2 & \Sigma y^2 \\ \Sigma x^3y & \Sigma y^3x & \Sigma x^2y^2 & \Sigma x^2y & \Sigma zxy & \Sigma xy \\ \Sigma x^3 & \Sigma y^2x & \Sigma x^2y & \Sigma x^2 & \Sigma zx & \Sigma x \\ \Sigma x^2y & \Sigma y^3 & \Sigma xy^2 & \Sigma xy & \Sigma zy & \Sigma y \\ \Sigma x^2 & \Sigma y^2 & \Sigma xy & \Sigma x & \Sigma z & N \end{vmatrix}}{\text{Principal Determinant}} \quad (26)$$

$$F = \frac{\begin{vmatrix} \Sigma x^4 & \Sigma y^2x^2 & \Sigma x^3y & \Sigma x^3 & \Sigma yx^2 & \Sigma zx^2 \\ \Sigma x^2y^2 & \Sigma y^4 & \Sigma xy^3 & \Sigma xy^2 & \Sigma y^3 & \Sigma zy^2 \\ \Sigma x^3y & \Sigma y^3x & \Sigma x^2y^2 & \Sigma x^2y & \Sigma y^2x & \Sigma zxy \\ \Sigma x^3 & \Sigma y^2x & \Sigma x^2y & \Sigma x^2 & \Sigma yx & \Sigma zx \\ \Sigma x^2y & \Sigma y^3 & \Sigma xy^2 & \Sigma xy & \Sigma y^2 & \Sigma zy \\ \Sigma x^2 & \Sigma y^2 & \Sigma xy & \Sigma x & \Sigma y & \Sigma z \end{vmatrix}}{\text{Principal Determinant}} \quad (27)$$

6. $z = Aw + Bx + Cy + D$

$$A = \frac{\begin{vmatrix} \Sigma zw & \Sigma xw & \Sigma yw & \Sigma w \\ \Sigma zx & \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma zy & \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma z & \Sigma x & \Sigma y & N \end{vmatrix}}{\begin{vmatrix} \Sigma w^2 & \Sigma xw & \Sigma yw & \Sigma w \\ \Sigma wx & \Sigma x^2 & \Sigma yx & \Sigma x \\ \Sigma wy & \Sigma xy & \Sigma y^2 & \Sigma y \\ \Sigma w & \Sigma x & \Sigma y & N \end{vmatrix}} \quad (28)$$

$$B = \frac{\begin{vmatrix} \Sigma w^2 & \Sigma zw & \Sigma yw & \Sigma w \\ \Sigma wx & \Sigma zx & \Sigma yx & \Sigma x \\ \Sigma wy & \Sigma zy & \Sigma y^2 & \Sigma y \\ \Sigma w & \Sigma z & \Sigma y & N \end{vmatrix}}{\text{Principal Determinant}} \quad (29)$$

$$C = \frac{\begin{vmatrix} \Sigma w^2 & \Sigma xw & \Sigma zw & \Sigma w \\ \Sigma wx & \Sigma x^2 & \Sigma zx & \Sigma x \\ \Sigma wy & \Sigma xy & \Sigma zy & \Sigma y \\ \Sigma w & \Sigma x & \Sigma z & N \end{vmatrix}}{\text{Principal Determinant}} \quad (30)$$

$$D = \frac{\begin{vmatrix} \Sigma w^2 & \Sigma xw & \Sigma yw & \Sigma zw \\ \Sigma wx & \Sigma x^2 & \Sigma yx & \Sigma zx \\ \Sigma wy & \Sigma xy & \Sigma y^2 & \Sigma zy \\ \Sigma w & \Sigma x & \Sigma y & \Sigma z \end{vmatrix}}{\text{Principal Determinant}} \quad (31)$$

IV. Example

The application of the method of least squares in the correlation of pilot plant data in connection with the catalytic dehydrogenation of normal butane is illustrated in this section. The data are presented in Figure 1. Since conversion, ultimate yield and yield per pass appeared to vary linearly with catalyst age (cycle number) between cycles 53 and 367, the problem concerned itself with the determination of the best straight lines through the data. The calculations of the equations of the best straight lines through the values of yield per pass and conversion are presented in Tables 1 and 2, respectively. Attention is directed to the fact that the definitions of conversion, ultimate yield and yield per pass are such that yield per pass is the product of conversion and ultimate yield. The best straight line through the values of ultimate yield was computed from the best straight lines through the values of yield per pass and conversion.

Acknowledgment

The assistance of B. J. Mayland and George Thodos in the development of this material is gratefully acknowledged. The author also wants to express his indebtedness to Phillips Petroleum Company for permission to publish this paper.

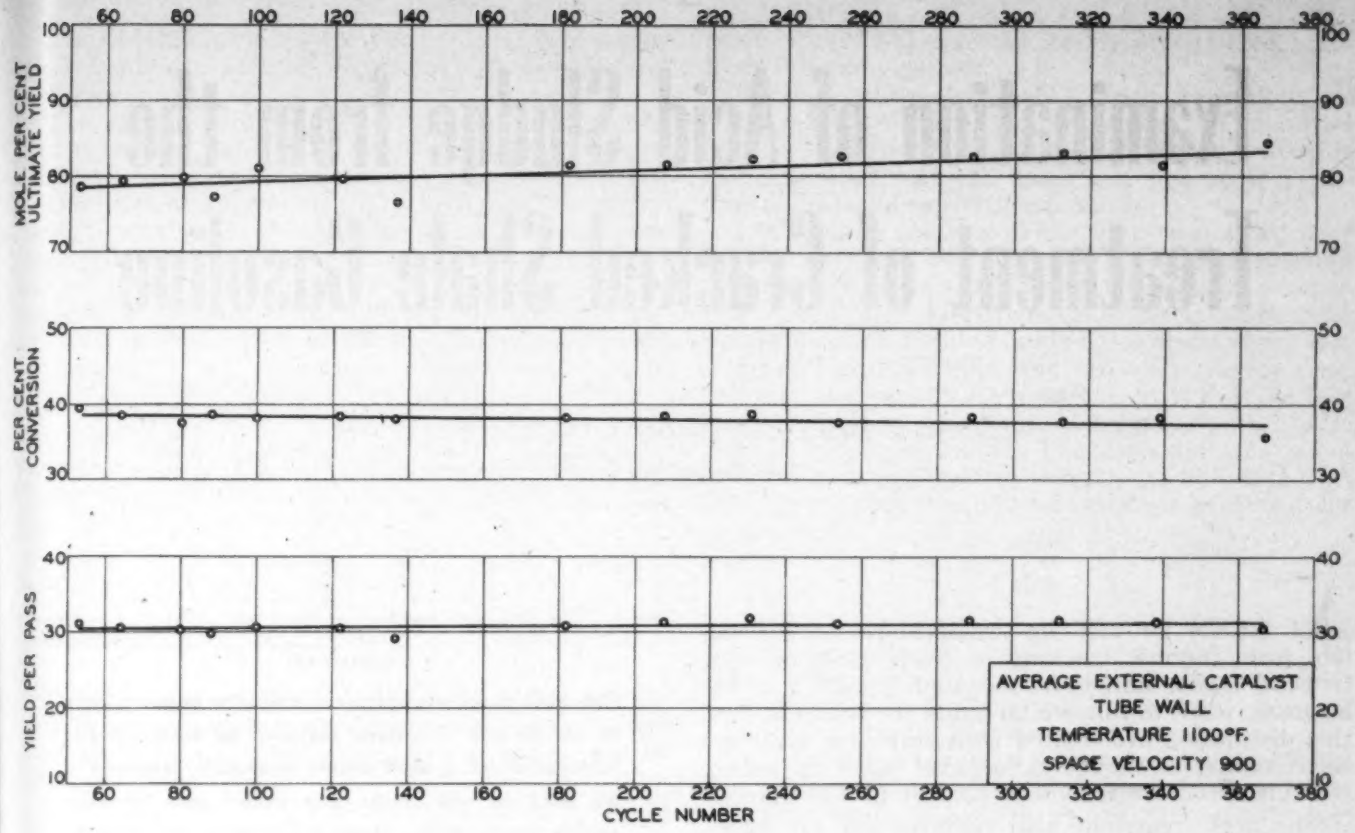

Figure 1

Effect of catalyst age on dehydration of normal butane with catalyst B.

TABLE 1

Catalytic Dehydrogenation of Normal Butane to Butylenes with Catalyst B — Effect of Catalyst Age on Yield Per Pass

(1) CYCLE NUMBER		(2) Yield Per Pass	(3) (1) x (2)	(4) $(1)^2$
	53	31.09	1647.77	2809
	64	30.75	1968.00	4096
	80	30.23	2418.40	6400
	88	29.94	2634.72	7744
	100	30.90	3090.00	10000
	122	30.54	3725.88	14884
	137	29.15	3993.55	18769
	182	30.97	5636.54	33124
	208	31.33	6516.64	43264
	231	31.88	7364.28	53361
	254	31.03	7881.62	64516
	289	31.46	9091.94	83521
	313	31.40	9828.20	97969
	339	31.14	10556.46	114921
	367	29.98	11002.66	134689
Summation	2827	461.79	87356.66	690067

TABLE 2

Catalytic Dehydrogenation of Normal Butane to Butylenes with Catalyst B — Effect of Catalyst Age on Percent Conversion

(1) CYCLE NUMBER		(2) Percent Conversion	(3) (1) x (2)	(4) $(1)^2$
	53	39.52	2094.56	2809
	64	38.74	2479.36	4096
	80	37.83	3026.40	6400
	88	38.81	3415.28	7744
	100	38.10	3810.00	10000
	122	38.41	4686.02	14884
	137	38.01	5207.37	18769
	182	38.11	6936.02	33124
	208	38.51	8010.08	43264
	231	38.81	8965.11	53361
	254	37.59	9547.86	64516
	289	38.13	11019.57	83521
	313	37.80	11831.40	97969
	339	38.30	12983.70	114921
	367	36.07	13237.69	134689
Summation.....	2827	572.74	107250.42	690067

Using Equation 15:

$$m = \frac{\begin{vmatrix} \Sigma y & N \\ \Sigma xy & \Sigma x \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} = \frac{\begin{vmatrix} 461.79 & 15 \\ 87,356.66 & 2827 \end{vmatrix}}{\begin{vmatrix} 2827 & 15 \\ 690067 & 2827 \end{vmatrix}}$$

$$m = \frac{1,305,480.33 - 1,310,349.90}{7,991,929 - 10,351,005}$$

$$m = \frac{-4,869.57}{-2,359,076} = 0.002064$$

Using Equation 16:

$$b = \frac{\begin{vmatrix} \Sigma x & \Sigma y \\ \Sigma x^2 & \Sigma xy \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} = \frac{\begin{vmatrix} 2827 & 461.79 \\ 690067 & 87,356.66 \end{vmatrix}}{\begin{vmatrix} 2827 & 15 \\ 690067 & 2827 \end{vmatrix}}$$

$$b = \frac{246,957,277.82 - 315,666,039.93}{7,991,929 - 10,351,005}$$

$$b = \frac{-71,708,751.11}{-2,359,076} = 30.40$$

Yield Per Pass = 0.002064 X Cycle Number + 30.40

Using Equation 15:

$$m = \frac{\begin{vmatrix} \Sigma y & N \\ \Sigma xy & \Sigma x \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} = \frac{\begin{vmatrix} 572.74 & 15 \\ 107,250.42 & 2827 \end{vmatrix}}{\begin{vmatrix} 2827 & 15 \\ 690,067 & 2827 \end{vmatrix}}$$

$$m = \frac{1,619,135.98 - 1,608,756.30}{7,991,929 - 10,351,005}$$

$$m = \frac{10,379.68}{-2,359,076} = -0.004400$$

Using Equation 16:

$$b = \frac{\begin{vmatrix} \Sigma x & \Sigma y \\ \Sigma x^2 & \Sigma xy \end{vmatrix}}{\begin{vmatrix} \Sigma x & N \\ \Sigma x^2 & \Sigma x \end{vmatrix}} = \frac{\begin{vmatrix} 2827 & 572.74 \\ 690,067 & 107,250.42 \end{vmatrix}}{\begin{vmatrix} 2827 & 15 \\ 690,067 & 2827 \end{vmatrix}}$$

$$b = \frac{303,196,937.34 - 395,228,973.58}{7,991,929 - 10,351,005}$$

$$b = \frac{-92,032,036.24}{-2,359,076} = 39.01$$

Percent Conversion = −0.004400 x Cycle Number + 39.01

Examination of Acid Sludge from the Treatment of Cracked Shale Gasoline

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SUMMARY

THE ACID sludge was hydrolyzed with water to give a black oil and an acid. This liquor contained tar bases (pyridine homologues) and a small amount of alcohols. Extraction of the black oil with caustic soda yielded some tar acids (mainly cresylic acids). Steam distillation of the extracted oil gave a heavy tar and a light distillate with a relatively low sulfur content.

AT GLEN DAVIS the stabilized pressure distillate from thermal cracking of crude shale oil in a two-coil Dubbs unit is fractionated to 265° F. After a caustic wash to remove tar acids the bottoms from this distillation are treated with sulphuric acid in a conventional two-stage Alfa-Laval plant to reduce the sulfur content from 0.45 percent to 0.25 percent.

The acid treatment also removes the tar bases, amounting to as much as 0.7 percent by volume of the charge, as well as the gum-forming conjugated diolefines.

The amount of acid required varies from 3 to 5 pounds per barrel, depending on the end point of the gasoline and the sulfur reduction required.

For disposal, the sludge is hydrolyzed with spent caustic liquors or waste process water to give an oil which is used as fuel. In order to see if greater use could be made of this material the following work was carried out with the primary object of obtaining an indication of its potentialities.

Examination of Sludge

Initial Hydrolysis

Approximately three liters of the acid sludge were well shaken with one and a half liters of warm water which was separated off. The residual tar was washed with 600 ml. of hot water and then shaken and stood overnight with another 600 ml. of water.

The combined aqueous extracts were clarified by filtration to give a beautiful clear deep orange-red solution.

The residual tar was washed with a further two liters of hot water and then with 1200 mls. of 10 percent caustic soda solution. An emulsion formed but broke cleanly on standing overnight. A further wash with a liter of water resulted in an emulsion which required several days standing before it broke completely.

Neutral Oils

The residual tar after caustic and water washing was considered to consist of "neutral oils."

It had specific gravity 969 at 60° F., and, though apparently dry, gave 7 percent of water on distillation. It contained 1.71 percent total sulfur.

The distillation residue (14 percent) was semi liquid when hot but it set on cooling slightly. Eighty milliliters of gasoline were merely discoloured when shaken with the residue which appeared quite dry and brittle but was fairly soft to the touch. After the gasoline wash the pitch was insoluble in gasoline or methylated spirits and only very sparingly soluble in benzene.

TABLE 1
Properties of Various Fractions from the Sludge

	Redistilled Neutral Oil	Steam Distilled Neutral Oil	Distilled Tar Bases	Tar Acids
Specific Gravity at 60° F.	.....	0.842	0.938	.....
Distillation °F:				
I.B.P.	140	281	240	172
5 Percent	295	299	296	259
10 Percent	308	308	348	369
20 Percent	328	324	362	382
30 Percent	352	332	366	386
40 Percent	377	338	370	388
50 Percent	405	345	375	390
60 Percent	454	355	379	395
70 Percent	523	363	385	400
80 Percent	580	378	391	406
90 Percent	.....	402	406	432
95 Percent	.....	443	418	.....
F.B.P.	582	480	435	457
Percent Distilled	83	96½	98	94
Percent Residue	17	3½	2	6

Sulfur Content

The distillate contained an appreciable amount of free sulfur. The heavy, viscous, final drainings from the condenser exhibited a strong blue fluorescence. On standing exposed to the air for several days the distillate became very deep red. The characteristics of this distillate on redistillation are given in Table 1.

The redistillation residue (17 percent) was a very viscous, almost black oil, soluble in both gasoline and benzene.

The lighter distillate was yellow and quite mobile and possessed the typical odor of the acid sludge. The later portion of the distillate was red and viscous.

One liter of neutral oil from the hydrolysis of the sludge was steam-distilled through a four-pear column. At the start severe priming and foaming occurred. From the start films of free sulfur became evident in the still head. The top temperature was allowed to rise slowly as the distillation progressed as follows:

Top Temp. °F	Mls. Oil	Mls. Water	Ratio: Water/Oil	Remarks
210	100	148	1.48:1	Oil colorless when collected, but soon became yellow.
216	44	66	1.50:1	
225	45	56	1.24:1	
240	56	70	1.25:1	
250	42	60	1.43:1	
256	39	64	1.64:1	
256	30	76	2.53:1	
otal	356	540	1.52:1	

The aqueous condensate had pH 6.0 to 6.5 by B.D.H. Universal Indicator and was slightly milky from the presence of free sulfur. It was not examined further.

The steam distillate, which amounted to approximately 36 percent of the neutral oil, has specific gravity 842 at 60° F. It was pale yellow but turned red on standing overnight exposed to the air. Its distillation range (see Table 1) suggested that it consisted largely of materials that had dissolved unchanged in the acid sludge.[4,5]

Although it contained 0.694 percent sulfur, the steam distillate was sweet to doctor test. It failed to give a precipitate with mercuric chloride in benzene soluion, but it gave some precipitate with saturated aqueous mercuric chloride solution. The aniline point of the distillate was 14.3° C.

This sulfur content is very low when compared with similar sludges obtained from other gasolines. For example Friedmann and Rodriguez[1] prepared a steam distillate containing 21.6 percent of sulfur from the sludge obtained by the sulphuric acid treatment of Panlaco gasoline.

Owing to the very small amount of the mercuric chloride complex obtained from the sludge distillate, no attempt was made to identify any of the sulfur compounds present.

The residue from the steam distillation was an extremely viscous black tar containing 1.93 percent sulfur and 0.49 percent nitrogen.

Effect of Exposure

Exposure to air caused the slow formation of a skin which gradually thickened over a period of several months. After standing for over a year the skin was brittle and powdered on handling to expose the unchanged tar beneath.

Tar Bases

The combined aqueous extract of the sludge was filtered and made alkaline to phenolphthalein with 40 percent caustic soda solution. On standing the precipitated bases formed a curdy layer on the top and some oil was formed.

The final water washings of the tar were made alkaline with caustic soda and then extracted with ether. The extracted liquor was discarded and the ether extract added to the freshly precipitated bases from the main extract.

The basic oil was separated from the aqueous liquor which was then twice extracted with small quantities of ether. An appreciable amount of ferric hydroxide had separated with the bases and this portion was filtered to make separation possible.

The ethereal solution of the bases was dried over solid caustic soda and the ether distilled off through a four-pear column until the top temperature reached 122° F. (51° C.). After removal of the ether the first fractions of the distilled crude bases smelt of organic sulfides. The distillation was cut when the top temperature rose rapidly from 400° F. to 410° F. At this stage the bottoms started to decompose with liberation of hydrogen sulfide. The distillate was stood over solid caustic soda to remove the hydrogen sulfide. On standing, the odor of ammonia became quite pronounced.

Color

The distillate was clear and highly refractive. The first 70 percent was practically colorless but the yellow color of the last fractions increased. The combined distillate was a clear, pale yellow liquid deepening in color on standing for several weeks.

The amount of tar bases in the sludge varied from time to time, but averaged over 10 percent by volume.

The tar bases isolated from the acid liquor after hydrolysis of the sludge are a complex mixture of pyridine homologues. Their distillation range (Table 1) shows that there is only a small proportion of the simpler bases present.

The distilled bases were dissolved in 50 percent hydrochloric acid. The solution of the basic oil was accompanied by the evolution of appreciable heat, the temperature rising to about 50° C. The acid solution became very deep red and a small amount of a "grey" oil filmed the surface.

When cool, the acid solution was extracted with ether to remove the neutral oils. The black ether extract was unchanged by washing with caustic soda solution. The ether was removed by distillation and the residual neutral oil, amounting to 0.5 percent by volume of the bases, distilled. Its distillation range corresponded closely with that of the pressure distillate and therefore suggested that it was composed of hydrocarbons that have dissolved in the sludge and had been partitioned between the tar base-sulphuric acid solution and the tar, on hydrolysis.

Solid Deposit

An appreciable amount of a red solid was deposited on the sides of the container holding the acid solution of the bases. Its appearance suggested that it was a "pyrrol red" type of polymerization product and it may indicate the presence of a small amount of pyrroles in the basic oil.

The bases were liberated as a brown oil from the acid by the addition of excess of 40 percent caustic soda solution and some ether was added to facilitate their separation.

On standing for three days the ether-base solution developed a strong dark green fluorescence visually identical with that of the crude oil. It is feasible that this fluorescence is due to the formation of compounds similar to the dipyrrolopyridones of Corwin and Ellingsen[2] which are reported to fluoresce in organic solvents remarkably like crude oils.

Careful fractionation of the purified bases through

a 36-inch Fenske column at high reflux was insufficient to isolate any pure material, only 6 percent distilling below 160° C.

Pyridine carboxylic acids may be formed by the oxidation of the side chains of the pyridine bases by concentrated sulphuric acid,[3] but attempts to detect them in the sludge or its extracts failed.

Tar Acids.

The clear reddish caustic extract was separated and acidified with concentrated sulfuric acid. It became cloudy and purplish and smelled strongly of cresylic acid. The acidified solution was twice extracted with benzene which, however, failed to remove the last traces of tar acids as shown by odor and chemical tests.

The benzene solution of the tar acids was carefully distilled to a top temperature of 230° F. (110° C.) to remove the majority of the benzene. The residue of the tar acids was deep purple and amounted to 29 c. c., i.e. approximately 1 percent of the acid sludge. This sample of tar acids was then distilled from a 50 ml. distillation flask using an atmospheric condenser.

These tar acids isolated from the sludge are present in it as free tar acids and not as their sulfonates. This is proved by their isolation from the sludge in the manner described as the sulfonic acids are not hydrolysed at the relatively low temperatures involved. Phenols are sulfonated by cold sulfuric acid to some extent[6] but, under plant operating conditions, only to about the same extent as aromatic hydrocarbons.[7]

Their presence in the sludge can be explained by their highly preferential solubility in the acid tar and the application of the laws of solvent partition. This is supported by the fact that their distillation range is characteristic of the tar acids obtained from the pretreat caustic wash of the pressure distillate. The high-boiling residue probably consists of alkylated phenols obtainted by the alkylation of the cresols by the olefines from gasoline; this reaction is catalysed by sulfuric acid[8] and has been employed on a commercial scale.

Alcohols

When the olefines present in the gasoline are treated with sulfuric acid, some polymerization takes place as well as the formation of small amounts of the acid and neutral esters of sulfuric acid. These reaction products are mainly removed as part of the acid sludge but some remain dissolved in the gasoline.[5] Concurrent or subsequent hydrolysis of the esters can give rise to secondary and tertiary alcohols.

Approximately one-quarter of the alkaline solution after the removal of the bases was kept standing until it possessed no odor of ether or of tar bases. It was acidified with sulfuric acid and steam distilled. The steam distillate was extracted with ether and the ether evaporated off to leave 0.2 to 0.3 c. c. of a light brown oil with a sweetish odor. This oil was dissolved in 5 c. c. acetic acid and 2 c. c. concentrated sulfuric acid added. The solution was boiled for about one minute and then poured into about 80 c. c. of water. An "ester" odor was immediately noticeable. The mixture was extracted with ether and the extract shaken with solid sodium bicarbonate. The ether was evaporated to leave 0.2 to 0.3 c. c. of a fragrant ester which evaporated spontaneously from an open dish in two days.

Sulfonic Acids

Sulfonic acids are formed by chemical reaction of the sulfuric acid with some of the constituents of the gasoline.

Aromatic hydrocarbons are fairly reactive towards sulfuric acid but the reaction is far from complete with normal refinery practice.[5] This is shown also by the negligible change in the proportion of aromatics in the treated and untreated gasoline. Phenols in the gasoline also may be sulfonated by sulfuric acid to some extent,[6] but under plant operating conditions to only about the same extent as aromatic hydrocarbons.[7]

Paraffins and naphthenes are resistant to the action of sulfuric acid at the temperature at which the refining process takes place but, in the presence of other materials which react with or dissolve in the sulfuric acid, appreciable quantities may dissolve in the acid sludge.[4,5]

The presence of sulfonic acids in the sludge was demonstrated by the foaming properties of all the aqueous extracts.

After extraction with caustic soda the residual tar was shaken with 1 liter of water. It emulsified and separated slowly over a period of several days. This aqueous extract had the color and appearance of milked tea. It foamed readily when shaken. On acidification it changed color abruptly to a dark blue-black and much of the color could be extracted with gasoline. The black gasoline solution was not decolorized by shaking with caustic soda. These observations can be explained by the sulfonic acids present acting as an emulsifying agent which held part of the tar as an oil-in-water emulsion.

However, the total amount of these materials present in the sludge was small and, as they tended to hydrolyze on boiling during their separation, no further attempt was made to isolate them.

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Maintenance of Tubular Heat Exchangers

J. G. HOUSMAN, Standard Oil Company (Indiana)

TUBULAR heat exchangers are an essential part of practically all units at the Whiting plant of Standard Oil Company (Indiana).

Exchangers are used as coolers, condensers, heaters and reboilers. The fluids passing through these exchangers vary from those being very viscous, such as tar, asphalt, and crude, to light gases and vapors such as naphtha vapor, hydrogen and steam. The frequency and extent of maintenance on a particular exchanger is largely dependent on the service of that exchanger, with service defined as (1) fluid combination, (2) temperature level and temperature differential, (3) pressure level and pressure differential, and (4) velocities of the fluids. Of these, the fluids and their ever-present contaminations are undoubtedly the most important and dominant factor.

A wide variety of material is used for the various parts of the exchangers, the more common ones being carbon steel, admiralty metal, chromium-molybdenum alloy steel, and high chrome-nickel stainless steel type alloys. The material selected originally is one which will withstand the anticipated type of corrosion, but occasionally a material change is made after some use. Such a material change is the result of unexpected or unusual corrosion or a change in the service of the exchanger.

Carbon steel is used most widely since it is the least expensive and the most readily available. It is used when the corrosion rate is relatively low, in general, of the order of 0.01" per year or less. Admiralty metal tubes are used in exchangers having water as one of the fluids. The use of admiralty greatly reduces scale formation on the water side and hence reduces the frequency of cleaning. Chromium-molybdenum and chromium-nickel alloy steels are used where corrosion cannot be satisfactorily reduced to permit the economic use of carbon steel.

This paper was delivered at the mid-year meeting of the Division of Refining, American Petroleum Institute, St. Louis, June 2 and 3, 1947.

THE removal of an exchanger from service for maintenance is regulated by the operating departments and the Inspection Department. Their basis for this removal may be (1) excessive pressure drop, (2) sufficient loss of efficiency to affect operation of the unit, (3) contamination due to leakage, (4) excessive external leakage, and (5) expected life based on previous records. Excessive pressure drop and loss of efficiency are the result of fouling whereas contamination is generally the result of corrosion. However, contamination and external leakage, and especially the latter, may be due to mechanical defects such as gasket leakage or leakage between the tubes and tube sheet resulting from faulty tube rolling. Past performance records, either with respect to fouling or corrosion, in many cases provide an accurate means of determining the necessity of maintenance work.

When a number of exchangers are arranged to operate in series, the efficiency loss of the entire group does not provide specific information as to the troublesome exchanger or exchangers. By checking the pressure drop across each exchanger, the exchangers requiring cleaning can be determined. For example, the pressure drop across an exchanger may increase from 6 psi when clean to 70 psi when very dirty. In the case of a single exchanger, the efficiency loss is generally sufficient to determine the extent of fouling, but this is not always true. For instance, some exchanger service results in concentrated fouling only at one section, usually near the inlet or outlet. Therefore, the overall heat transfer is not appreciably affected, but the pressure drop may be materially increased. With an exchanger in this condition, erosion may result due to localized high velocities. In one case at the Whiting refinery, a hole was eroded through the shell in the vicinity of the drain notch at the bottom of a baffle after the entire cross-section of a pass was solidly plugged in this area except for a passage through this drain notch. Also excessive pressure drop may overload the existing pumping equipment. Therefore, in general, the pressure drop across the various exchangers on a unit is periodically determined and recorded.

Disassembly Problems

Contamination may or may not be serious, depending on the two fluids passing through the exchanger. For example, some leakage of crude into a reduced crude stream is not objectionable, but leakage of any substance into a semi-finished product stream results in an immediate removal of the exchanger from service. In some cases contamination is permitted until the capacity of the pump or other mechanical equipment is affected.

A persistent source of trouble in the disassembly of our exchangers has been unbolting the external flanges. With an exchanger using large and relatively few retaining bolts, it is often difficult to supply sufficient force to break the nuts loose. The impact wrenches available for this operation are frequently inadequate. It has been the experience of our maintenance department that a larger number of small diameter retaining bolts is much more desirable than the larger and fewer number retaining bolts. A wide variety of bolt lubricants have been used in the past with the most common one being a mixture of graphite and high volatile oil. However, recently a colloidal copper coating has been used with improved results.

The removal of the tube bundle is difficult if heavy deposits exist on the shell side of the exchanger or if the baffles bind on the shell due to warpage of the tubes. Normally, the bundles are pulled by the use of a chain fall. If sufficient force cannot be applied in this manner, mechanical or hydraulic jacks are used against the floating tube sheet to supply the required additional force. These jacks are arranged so as to act between the floating tube sheet and the shell with a

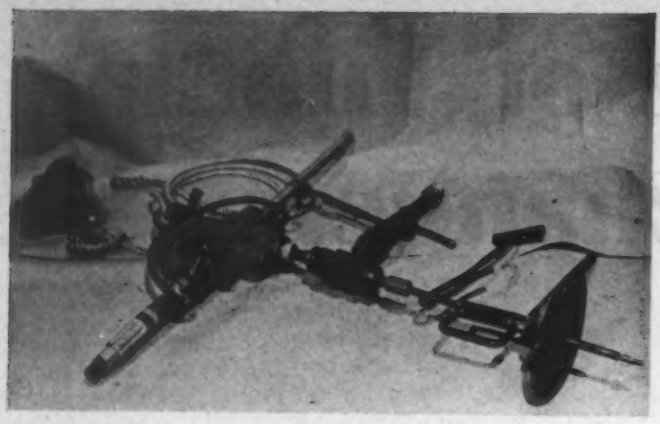

Figure 1

large wood cushion block placed against the tube sheet for protection against localized damage. In several cases even this combination of effort has not been sufficient to move the bundle. However, by removing the insulation from the outside of the shell and then striking the shell with heavy mauls, coincident with the application of the maximum permissible force, it has been possible to "inch" the bundle out of the shell.

Cleaning Methods

Mechanical cleaning has been in the past and still is the primary method of cleaning heat exchangers at the Whiting refinery. If the shell side is relatively clean, but the tube side requires cleaning, it is not necessary to pull the tube bundle, but only to remove the channel cover, the shell cover, and the floating head cover. Steam, water, air, and mechanical drilling are used to clean the tubes depending on the type and amount of deposits, with mechanical drilling the basic operation. The drilling equipment, shown in Figures 1 and 2, consists of an air motor, a spindle, a hollow shaft the length of the tubes, and an attachable drill.

The drill used at present is a commercial product, but in the past the end of the tube was simply ground to provide a cutting edge as shown in Figure 2. A monorail is erected parallel to the tube bundle to support the air motor, spindle, tube, and drill assembly. Air, water, or steam is transmitted through the spindle and the hollow shaft to carry the deposits out of the tube as the drilling progresses. The funnel

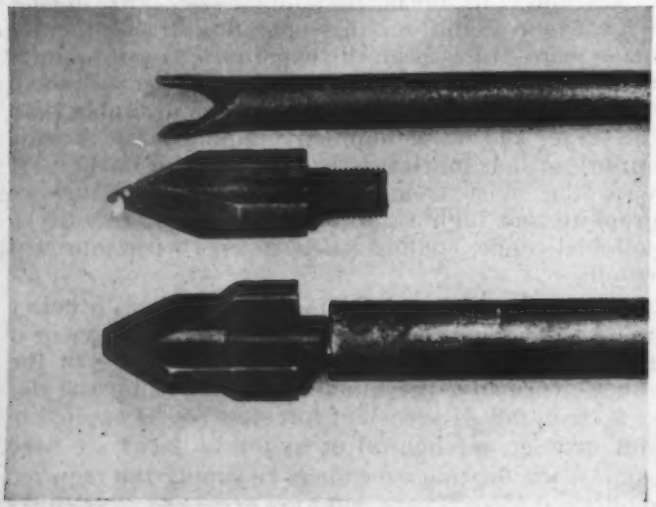

Figure 2

shaped shield, through which the hollow tube extends, protects the operators from the dirt which is blown out of that end in the event of a plugged tube. After completion of the drilling, the inside surfaces of the tubes are usually sandblasted.

For mechanically cleaning the shell side of the exchanger, it is necessary to remove the tube bundle. The bundle is generally cleaned immediately outside of the shell while resting on a permanent or temporary platform. If the deposits are concentrated and cannot be removed by a water or steam wash, large "saws," shown in Figure 3, are used to remove the major portion of the deposits. These "saws" are made from soft sheet metal and are of sufficient length to pass through and extend beyond the bundle. The main difficulty with this method occurs when attempting to remove gummy deposits since these deposits tend to accumulate on the inaccessible portions of the inner tubes. The inside of the shell is cleaned by sandblasting.

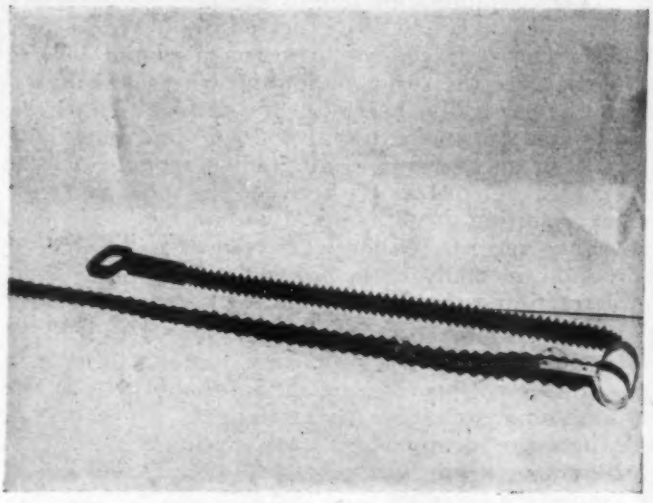

Figure 3

The cleaning of exchangers has not been confined entirely to mechanical methods. Various chemical and hydraulic methods have been tried with fairly good success. The most successful of these has been a simple hot water wash with the exchanger left completely assembled. Of course, this method is limited to deposits which are water soluble. Additional experimentation is contemplated for the future and it is expected that in general the cleaning time will be reduced.

Extensive fouling consists primarily of salt or coke deposits. The salt deposits occur almost exclusively during the preheating of crude. These salts remain in solution until the crude reaches the vicinity of 300° F. As the temperature rises, increasing amounts of salts are deposited in the passages. Thus, when a group of exchangers are in series and used to preheat crude, the worst fouling generally occurs in the last exchanger. Also, with the refining of increasing amounts of West Texas crude, having a greater salt content that the other crudes, the fouling of crude exchangers has appreciably increased. Desalting equipment is being or has been installed on units which formerly did not require such equipment. For example, from May to September, 1944, a mixture of Mid-Continent and West Texas crudes, the mixture containing about 17 percent of the latter, was processed in our No. 370 combination cracking unit. The crude was not desalted and, even with the

Figure 4

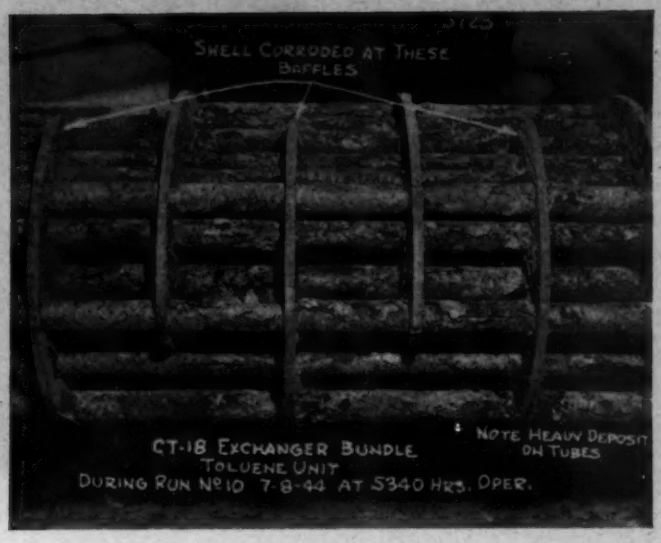
SHELL CORRODED AT THESE BAFFLES
NOTE HEAVY DEPOSIT ON TUBES
CT-18 EXCHANGER BUNDLE
TOLUENE UNIT
DURING RUN NO 10 7-8-44 AT 5340 HRS. OPER.

Figure 5

low percentage of West Texas crude, the fouling of the higher temperature crude exchangers increased to such an extent that this method of operation was abandoned until desalting equipment could be installed. The corrosion rates also showed a marked increase during this period of operation. Examples of severely fouled heat exchanger tube bundles are shown in Figures 4 and 5.

All exchangers which are partially or completely disassembled are inspected by the inspection department. The inspection consists of a visual check, physical measurements, and when found necessary,

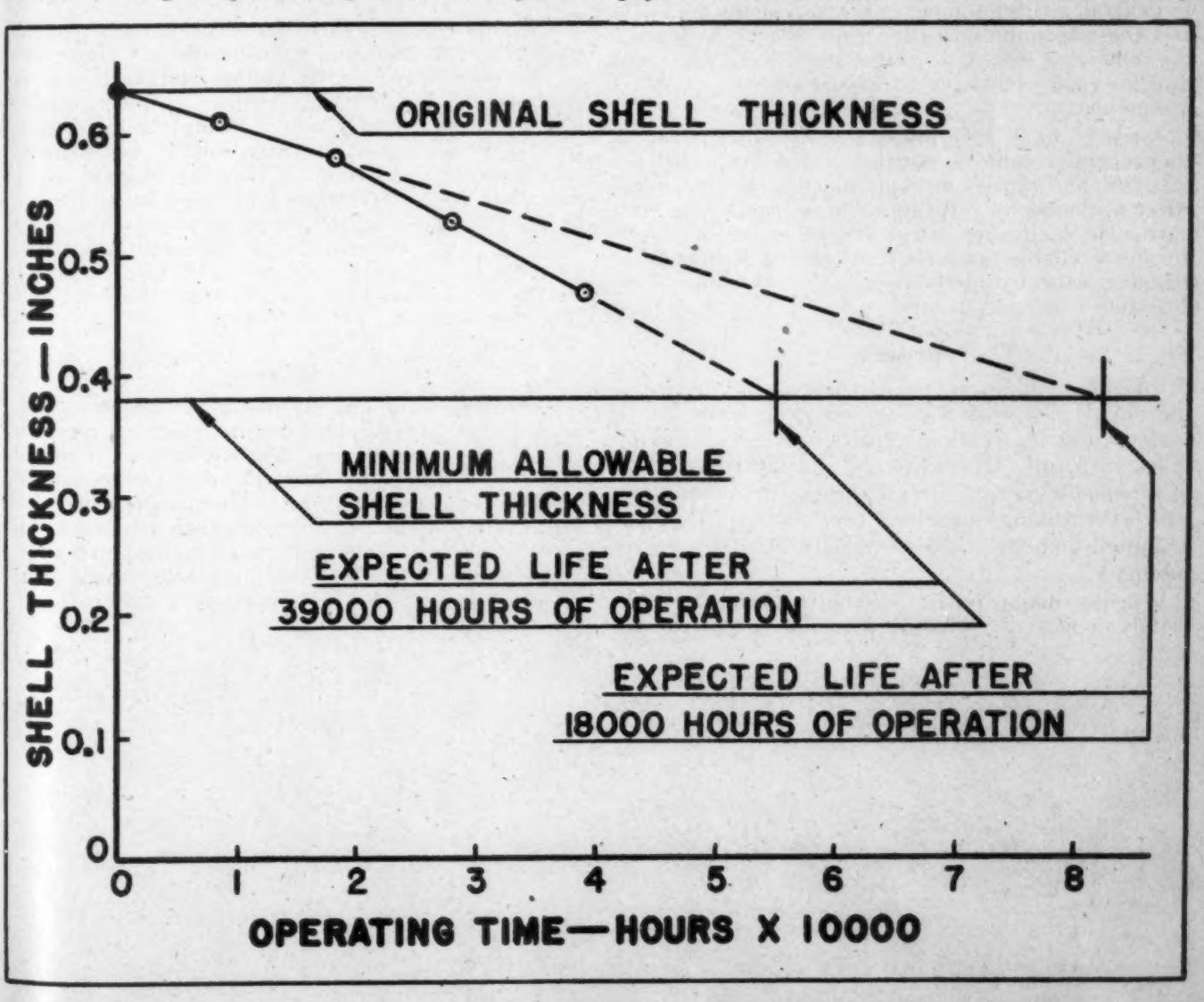

Figure 6
A graphical method used to predict the remaining life of exchangers

Figure 7

magnaflux examination. The use of magnaflux examination has been confined to the inspection of welds. The extent of the physical measurements depends to a large extent on the visual check. In cases of a complete disassembly, however, all of the component parts are at least spot checked, primarily as a basis for determining corrosion rates. Figure 6 illustrates a graphical method used for this determination. In general, a large number of measurements are made and the maximum corrosion rate is used to predict the remaining life. After the inspection the corrosion rate for each exchanger is revised and the expected life predicted.

A report on all such inspections is issued covering the general condition, corrosion rates, expected future life, and repairs or replacements recommended. After a number of inspections have been made on a particular exchanger, these inspection reports constitute a reliable basis for determining frequency of cleaning, expected life of each part of exchanger, and desirable material changes.

Repairs

All minor repairs on exchangers are performed in the field. Field work includes rerolling leaky joints, various minor welding repairs, plugging leaking tubes with solid tapered plugs, and the replacement of removable parts. Figure 7 shows a tube bundle in which the leaking tubes have been plugged to permit a limited amount of additional operation before retubing.

When a major repair is required, such as completely or partially retubing a bundle or remachining gasket surfaces, the parts concerned are removed from the unit for repair in the machine shop. Facilities for remachining a gasket surface of a tube sheet with the tubes intact are planned for our machine shop, but at present this work on a tube bundle is performed by outside shops.

Reassembly

The reassembly of exchangers is relatively trouble-free since the shell and tube bundle are clean, and interference between the baffles and shell can be removed by grinding the baffles. However, gasket leakage is occasionally found during the hydrostatic test. In most cases it has been found more satisfactory to reuse the gaskets if they are in good condition than to replace them with new ones. The asbestos-filled gaskets are sometimes preferred over the solid soft steel and straight asbestos gaskets. However, all three types have been used. Occasionally it has been necessary to cut our own gaskets from sheet metal stock.

Conclusion

There are an unlimited number of problems connected with any maintenance program, and certainly the one covering tubular heat exchangers is no exception. In this paper only the most common problems and the most general maintenance procedures are covered briefly. Although corrosion is one of the foremost causes leading to heat exchanger maintenance in any refinery, it has only been briefly mentioned here because it in itself is a major subject for discussion.

Corrosion Studies

FOR THE PETROLEUM REFINING INDUSTRY

PART 2.

Factors Affecting Corrosion

F. A. ROHRMAN
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MUCH of the misunderstanding relative to corrosion studies is due to the failure to comprehend the nature and intensity of the many factors involved. The vagaries of these influences are often quite complex. A natural classification into influences inherent within the metal, in the solution, and externally seems to present itself. The classification may be as follows:

THE METAL

1. Electromotive position
2. Purity
3. Nature of impurities
4. Physical state
5. Oxide or surface behavior

THE CORRODING MEDIUM

6. Salt solubility
7. Nature of cation
8. Concentration of cation
9. Electrical conductivity
10. Diffusivity {Temperature / Viscosity}
11. Nature of anion
12. Nature of corrosion products

EXTERNAL INFLUENCES

13. Oxygen concentration
14. Light
15. Colloids
16. Bacteria
17. Cathodic metals
18. Stray currents

In the discussion of each factor it will be necessary, then, to assume that none of the other factors interfere. Actually such a state never occurs, but it should be posited for the purpose of clarifying each phenomenon involved.

1. *Electromotive position.* From the previous explanation it should be evident that the metals in the upper portion of the electrode potential series are more subject to corrosion than those in the lower portion. Thus, in nature, gold, silver, copper, and mercury occur in the free state, while aluminum, zinc, iron (other than meteoritic), and lead are never found uncombined.

One expects to find, and does find, that salt water, acid solutions, or copper sulfate solutions will attack clean (oxide-free) aluminum more readily than they will attack zinc, and zinc more readily than copper, and copper more readily than gold. The series then, gives one the first impression of the corrodibility or corrosion resistance of the elements as a group.

2. *Purity.* It has frequently been argued that if an element could be freed of all impurities and be perfectly homogeneous it would resist solution in any medium. Theoretically such a perfect metallic state could exist; actually it does not, because no element has ever been relieved of all its impurities nor been in a homogeneous state, nor is it feasible to prepare such a metal. Therefore it is doubtful whether the reasoning can be proved. It is known, however, that as a metal is purified its resistance to corrosion increases. The explanation for the greater corrosion resistance of the purer metal is perhaps to be based upon the non-existence of local-action currents which are dependent on the presence of dissimilar metals or the existence of heterogeneity of structure. In other words, if the metal is free of other elements and absolutely homogeneous no potential can possibly exist between one point on the surface and another; therefore no current can flow and the metal will not go into solution.

The insolubility of high-purity zinc in acids is a good example of the effect of impurities on the corrosion of metals. Zinc containing less than 0.0001 per-

THIS is the second section of a three-part study. In the first section, which appeared in the June, 1947, issue of Petroleum Refiner, the author discussed the economics of corrosion prevention and basic corrosion theory. In this issue Dr. Rohrman continues with notes on the factors affecting corrosion, and in an early issue the final section which deals with corrosion testing and corrosion prevention will be presented.

The serious economic losses occasioned by corrosion are well known to operating engineers and maintenance men. The total loss is greater than the cost of corroded materials and replacement as other factors such as loss of time and products, product contamination, and damages incurred by equipment failure, may far exceed specific corrosion losses.

Routine inspection and replacement long has been the conventional answer to corrosion difficulties, with such measures as the use of more resistant construction materials, water treatment, counter-electrolytic protection, and others, reserved for the "difficult" cases. In some degree, this is the best procedure, as the problem is primarily an economic one, with the lowest overall cost the desirable result. Great progress has been made in recent years in combatting corrosion, with several methods demonstrating definite value in refinery applications.

Because we have received many inquiries on corrosion problems and prevention methods it is believed that this present work will be of real value to plant men, especially so since it is written in language that can be understood by those who are not specialists in this field.

Since the first article of this series was printed in the June issue, the author has assumed his new duties as executive director of the engineering experiment station of Colorado University, Boulder.

Dr. Rohrman until recently was head of the Department of Chemical Engineering, Kansas State College.

cent impurities has been prepared by electrolysis and vacuum distillation. This zinc resists solution nobly and remains untarnished in the atmosphere for months, while a 99.90 percent zinc corrodes or becomes covered with a gray film. The 99.90 percent zinc, in turn, resists corrosion more readily than a 99.00 percent zinc, etc.

Iron prepared by electrochemical means is quite pure and resists attack in a surprising manner. A number of patents have been granted covering the manufacture of electrolytic iron pipes and tubes, the extra cost in manufacturing supposedly being balanced by the greater life of this iron.

3. *Nature of Impurities.* The impurities in a metal are of two kinds, those more noble and those more base. The latter will not promote the corrosion of the metal in question, because their solution pressures are greater than that of the main body of metal; consequently, they will go into solution first. For this reason aluminum and magnesium, being more base than zinc, will be preferentially dissolved when present in this metal. On the other hand, iron, copper, etc., being more noble than zinc, will act as cathodes, and zinc as the anode.

Too often it is believed that the potential of the more noble constituents is of consequence in determining local-action currents, but according to the fundamental equation (6), where the sole factors

$$E_m > E_h + E_v \qquad (6)$$

involved in acid corrosion are the potential of the less noble metal, E_m, the potential of hydrogen in the medium, E_h, and the hydrogen overvoltage on the metallic impurity, E_v. The only function of the more noble constituent is to act as a focal point for the deposition of hydrogen. In other words, the only role the impurity constituent has to play in corrosion is that of acting as a point for the evolution of hydrogen.

A proof of this basic fact is that zinc and mercury are far apart in the electromotive series (1.61 volts) yet it is known that amalgamated zinc is only very slowly dissolved in acid. The reason for this becomes evident upon noting the high hydrogen overvoltage on mercury, a factor that makes for a low value in the equation just given. Because of the low hydrogen overvoltage on iron or platinum, additions of these metals to the zinc result in rapid solution and consequently lead to a high corrosion rate.

4. *Physical state.* The physical state or the heterogeneity of a metal has an important bearing upon its electrode potential and its rate of solution. If the potential of any piece of metal is measured and a stress or strain is then imparted to it, the potential of the stressed area will become negative to a slight extent over the unstrained or unstressed area. This difference can be easily measured as a potential difference in either pure or impure metals and may sometimes amount to several tenths of a volt. A stress or a strain may be imparted to a metal by three means:

(1). Physical disturbance at temperatures below the annealing point.

(2). Rapid quenching from temperature above the annealing point.

(3). Electrodeposition at high current densities.

Usually these three cases manifest themselves by a change in crystal structure. Yet, it is known that energy is absorbed in the processes.

Too often metallic specimens are tested for resistance to corrosion without regard to their physical property or state. A metal may be sawed or cut for a sample, drilled for a holder, filed, or polished; each one of these operations imparts to the metal a strained area which differs in corrosion resistance from that of the main body of metal. The result is that corrosion will be more pronounced at the edges and around the holes, and the immediate rate of solution will be higher than its later rate of solution.

The effect of repeated stress or strain on a metal should not be under-emphasized. Very often metals are exposed to corroding media and subjected to repeated stress at the same time. A good example of this dual action may be that of a reciprocating pump used for corrosive mine waters or sour petroleum crudes. The number of failures under such conditions is quite large and affords considerable investigation toward means of avoiding this undesirable condition. The excellent and important researches of McDonald and his colleagues at The Illinois Institute of Technology are very revealing in this respect.

When the crystals of a metal are broken up it is easy to see that a greater surface results and that the solution rate should increase for this reason alone. Mere rate of solution without any increase in heat does not connote a potential increase. Thus, two small pieces of metal may have the same potential as one large piece, but they dissolve faster than the large one because of the greater surface exposed. It is also known that the different sides of a crystal grow and dissolve at different rates. As a crystal is broken up, more of the more soluble sides are exposed, and these may have a greater potential than the less soluble sides. As a metallic body is changed from a large crystal structure to a small crystal structure the grain boundaries become focal points for local action cells because of the greater number of impurity segregations at these points. It is then possible that a stress or strain will hasten corrosion by virtue of atomic distortion, smaller crystal structure, presentation of more soluble crystal faces, uncovering of impurities, etc. It is also known that fairly rapid corrosion may take place at the edges and corners of electroplated objects because at these points the current densities are higher and smaller crystals are deposited.

In industry it is known that corrosion will be more acute at rivet points and the machined portions of fabricated equipment. It is becoming good practice to anneal even large fabricated parts after mechanical work in order to reduce the localized strained areas.

Of general interest is the importance of stress-strain corrosion in criminology. It is known that revolvers and pistols are numbered by steel dies and such numbers would often lead to the identification of the owner. Owners of such weapons for illegitimate purposes file or grind out these numbers, thus try to prevent identification. When a number is stamped on a metal, however, a strain facsimile of each number is outlined into the body of the metal, so that even if the number is obliterated on the surface it is potentially present below the surface. Criminologists employ acids to etch into the strained areas and reveal the outlines of the number.

5. *Oxide or Surface Behavior.* Most metals are rapidly attacked by oxygen to form oxides, especially at higher temperatures. Some of these oxides are quite soluble and others are not. As a rule, the metals below hydrogen in the electrochemical series form oxides which are quite soluble while those above hydrogen form oxides which resist solution. If a metal forms an oxide which is insoluble, adherent, and tends to cover the surface

of the underlying metal thoroughly, then such a metal will be protected from chemical attack by this oxide. Oxides are rarely as good electrical conductors as are the metals; consequently the attack on the surface will be chemical rather than electrochemical. The same type of oxide is responsible for the protection of magnesium, aluminum, iron, and many of the stainless steels. As previously mentioned, the reason why aluminum and chromium resist corrosion so well despite their negative potentials is because of the oxide films which form on these metals. The existence of these films is not hypothetical; they actually have been isolated and their thickness determined. It is noteworthy that the metals below hydrogen in the electromotive series do not form protective films but that they act quite oppositely. Copper, silver and mercury resist solution except in the presence of oxygen or oxidizing agents. The usual method for dissolving these metals is to expose them to oxidizing agents. Strong non-oxidizing acids have very little effect upon them, while dilute or concentrated nitric acid reacts vigorously with them to form the nitrates.

Oxide films which tend to protect the underlying metal from chemical action are called passive films, and the phenomenon is known as passivity. It has been determined that an oxide film becomes a passive film when it is slightly soluble, adherent, and when less than 1/1000 of the base metal is exposed.

A simple and interesting experiment can be performed to demonstrate the protective nature of the oxide film on aluminum metal. If an aluminum bar is properly treated it can be amalgamated. The effect of the mercury on the aluminum surface is to prevent the formation of a continuous oxide film. Aluminum tends to oxidize immediately upon exposure to air and oxygen. Normally, this oxide film would be protective but since the mercury prevents such an adherent film to form the aluminum oxidizes continuously with the formation of a thick, non-adherent layer of oxide. If the bar is constantly rubbed so as to remove the oxide formed it gets so hot that it cannot be held in the hands. Should this bar be placed in water or any corroding medium while it is amalgamated, hydrogen will be displaced as bubbles, demonstrating the susceptibility of aluminum to attack. The high hydrogen overvoltage of hydrogen upon mercury does not deter this reaction because of the high solution pressure of aluminum.

Protective oxides may be accelerated or encouraged to form on metals by exposure to atmospheric oxygen or oxidizing agents such as nitric acid, chromic acid, dichromates, etc. Thus, it is common practice to subject some of the stainless steels to strong oxidizing agents in order to build up a thicker coating of protective oxide.

There are other types of passive films that may be induced to form upon metals. Passive phosphate coatings have the greatest of industrial value. Such films are produced on metals by exposure to phosphoric acid or phosphate salt solutions. Iron is the metal most always protected by phosphate films. The best known of the many phosphate processes are the Parker and Bonder processes which are modifications of the original Coslett process. It is interesting to note that the early Romans employed phosphate minerals to protect iron. One then may be induced to question the validity of the patents behind these processes.

Iron, being below aluminum and above copper in the series, behaves most unpredictably with oxygen. In most cases the oxide film is not protective, especially in water and the atmosphere. In strong oxidizing acids such as concentrated nitric acid or nitric acid-sulfuric acid mixtures, iron is protected by a protective oxide film.

The Corroding Medium

6. *Salt Solubility.* As a metal is attacked by a corroding medium it combines with the ions of the medium which may be present. If the combination produces a soluble compound corrosion will continue at a steady rate. This accounts for the avid action of lactic acid, sulphanillic acid, and other acids which produce soluble salts upon metals. On the other hand, if the metal and medium form insoluble compounds two phenomena are possible. If the resulting compound is insoluble, adherent, and non-porous it may act as a protective film for the metal, and corrosion will be hindered. If this compound is insoluble, but not adherent, corrosion will be continuous because the metal ion concentration will always be low and cause a continuous negative electrode potential. The corrosion of copper in sodium iodide solution is typical of this last case.

7, 8. *Nature of the Cation and its Concentration.* According to most evidence, over 95 percent of all corrosion is the result of acid corrosion; that is, corrosion due to the substitution of metal for hydrogen in the corroding medium. It is just as possible for metallic salt solutions to react upon metals as for acid solutions, but the latter solutions are the ones most frequently encountered. The reactions are precisely the same except that hydrogen is displaced in one case and metal in the other. Copper sulphate solutions attack the base metals with facility, the copper displacing the more negative metal.

If a certain base metal were exposed to iron chloride, tin chloride, hydrogen chloride, copper chloride, and gold chloride the action would be more vigorous as we proceeded from the iron to the gold chloride if the other factors remained the same.

The corrosion of metals by mine waters often is complicated by the presence of displaceable metals, or rather metal ions. Certain kinds of brasses sometimes are corroded severely because of the partial solution of the copper component and its reprecipitation by displacement with the zinc atoms, a phenomenon known as dezincification.

It was demonstrated that the influence of the cation concentration is important in determining the potential of an electrode. It suffices to repeat that as the concentration increases for a particular electrode, its potential becomes more positive. The behavior of strong oxidizing acid solutions in contrast to the same acids when dilute often produces opposite results. Iron resists strong sulfuric acid but not dilute sulfuric; aluminum resists strong nitric acid but not dilute nitric. This is because the stronger oxidizing acids promote the formation of insoluble oxide films more readily than the weaker acids.

From the previous discussion it should be evident that most acid solutions become more corrosive as their concentration is increased. We naturally expect a strong acid solution of hydrochloric acid to be more corrosive than a weaker solution of the same acid. This normal behavior is not the rule, however. The concentration-corrosion rate curves for some acids upon some metals illustrate some interesting data. Sulfuric acid has the most pronounced action upon iron at a concentration of about 13-normal (40 to 50 percent H_2SO_4. Acetic acid attacks aluminum most

readily at the very low and the very high concentrations whereas the intermediate concentrations are without perceptible action.

Water, the most common corroding medium, has a very low hydrogen-ion concentration. Pure water has a concentration which may be expressed as 10^{-7} gram ions per liter. The hydrogen potential at 25° C. will then be

$$E_{H^+} = E_o + 0.059 \log 10^{-7}$$
$$E_{H^+} = O - 0.413$$
$$E_{H^+} = -0.413$$

It is, then, quite unlikely that this concentration of hydrogen ions will severely attack metals having potentials more positive than —0.413. Thus, nickel, if in a normal solution of its ions and if the solution has a hydrogen-ion concentration of 10^{-7}, would not be affected. If, however, the concentration of nickel ions were 10^{-7}, corrosion could take place because

$$E_{Ni^{++}} = -0.23 + \frac{0.059}{2} \log 10^{-7}$$
$$E_{Ni^{++}} = -0.437$$

The nickel potential is now less noble than the hydrogen potential by 0.024 volt. The attack would be of the hydrogen depolarizing type rather than the hydrogen evolving type owing to the hydrogen overvoltage upon nickel being in the order of 0.29 volts.

When a metal is placed in a medium having an unknown or insignificant content of its own ions it is impossible to calculate what the potential relationships should be. Moreover, since the potential depends upon the ionic concentrations at the faces of the electrodes, one is not always right in basing his calculations on the concentrations in the body of the liquid. If a negative electrode is placed in a solution very low in concentration of its own ions the potential will invariably be more positive than one would expect, because the metal-ion concentrations at the anodic areas are always higher at the interface metal-medium on account of the slow rate of diffusion of the dissolved metal into the body of the liquid. At equilibrium, however, the concentration must be the same.

If nickel or almost any other metal is placed in a solution of sodium chloride its potential, of course, will be more negative than if it had been placed in a solution of its own ions. It would immediately go into solution and its ions would diffuse into the body of the liquid. Soon its potential would be as high as the hydrogen potential, and attack would cease.

9. *Electrical Conductivity.* Corrosion being an electrochemical phenomenon, it can be seen that the electrical conductivity of the corroding medium has a direct effect upon the solution velocity of the attacked metal. The medium must be conductive to local-action currents, for otherwise local action would cease. There often is a direct relationship between the conductivity of the acids or media attacking metals and the solution rate. The usual increase of hydrogen-ion concentration with the conductivity must not be considered as the prime reason why the solution velocity increases. The effect of the hydrogen-ion increase would make the value of the reaction velocity change according to the log H^+, and not directly, as the conductivity does.

10. *Diffusivity and Temperature.* The concentration changes which might alter the electrode potentials are dependent upon the rates which diffusion will proceed. It can be said that diffusion increases with an increase in temperature or circulation and with a decrease in viscosity, while viscosity decreases with an increase in temperature. The rate at which dissolved oxygen is delivered to the electrodes is also dependent upon the rate at which the solution is circulated.

Besides affecting diffusion in the manner outlined, temperature affects the electrode potential according to the Nernst relation, $\frac{RT}{nF}$ C. where T is in Kelvin degrees. The hydrogen overvoltage on metals is also reduced by an increase in temperature. As secondary effects, salt solubility generally increases and oxygen solubility decreases with a rise in temperature. This section then presents a maze of possibilities often difficult to interpret.

11. *Nature of Anion.* It is a well-known fact that the metals which form protective oxide films are only slowly dissolved in sulfuric acid, nitric acid, and many other media. Since most of these metals form soluble sulfates and nitrates, their insolubility must result, not from salt insolubility, but from oxide insolubility. The halogen acids react with these oxides, however, so that traces of chlorides, flourides, or bromides in corroding media cause these metals to go into solution much more readily than if the halides were absent.

It is believed by some that the halogen ions are smaller, and have the ability to penetrate the small openings of the oxide film and attack the metal. Yet one must reason that mere accessibility of anions to the metal does not necessarily result in corrosion; with metals of the passive film type, corrosion is an immediate consequence of hydrogen substitution, and hydrogen is a much smaller ion than any of the halogens. It must follow, then, that the action of the halogen is a secondary one, and it is quite possible that its role is one of combining with the oxide to form a soluble halide. Some practical aspects of this influence are illuminating. During the electrolytic deposition of nickel it is necessary that some chloride be present in the sulfate bath in order to facilitate anode solution. Without the chloride, or other halides, very little nickel goes into solution and the bath soon becomes depleted of nickel; a condition to be avoided. In some sections of the country it is the practice to apply calcium chloride to roads in order to lay the dust or to add salt to icy streets. These practices prove rather tragic to automobile parts plated with chromium or nickel, for when the roads become wet these parts are splashed with these very active media and rapidly corrode.

Metallurgists have constantly been attempting to perfect a ferrous alloy which would resist hydrochloric acid. All the "stainless" ferrous alloys resist corrosion because of their homogeneity and their possession of non-permeable oxide film. Since the resistance of these metals depends chiefly upon maintaining this oxide film which combines with the halogens, they are resistant to all media except those containing halides.

12. *Nature of Corrosion Products.* This topic is closely related to topics 6 and 11. Let us assume that the metal to be corroded is zinc and that the corroding medium is a sodium chloride solution. From theory we can assume that the following reactions can take place:

$Zn \rightarrow Zn^{++} + 2e$ ..... at anodic points
$H^+ + e \rightarrow H^*$ ..... at cathodic points
$Zn^{++} + 2OH \rightarrow Zn(OH)_2$ ..... In body of solution
$Zn^{++} + 2Cl \rightarrow ZnCl_2$ ..... In body of solution

The formation of the zinc chloride or zinc hydroxide will depend upon the hydrogen ion concentration and the chloride ion concentration, a high concentration of the former and latter encouraging the forma-

tion of zinc chloride. Complex compounds may alsc form, but their formation will not be discussed here.

On the basis of their physical nature and behavior, possible corrosion products may be placed in these groups:

1. Those which are soluble.
2. Those whose presence encourages passive film formation.
3. Those which prevent passive film formation and are not soluble.

If the product is only slightly soluble and has a tendency to adhere to the metal surface, forming a protective film, corrosion will not take place, as in the previously cited example of lead sulfate. Those compounds which act as screens to oxygen will cause preferred attack taken up under the next heading.

Everyone is familiar with the appearance of iron rust. The mechanism of its formation is quite simple. Most iron rust is evidenced where the corroding medium has been ordinary water. The iron goes into solution as ferrous iron (Fe^{++}) and ferrous hydroxide has a whitish green color, while rust as we see it, is red; another reaction must therefore enter in. What happens is that the oxygen of the atmosphere enters into the reaction at this point and the ferrous ions are oxidized to ferric ions, the result being ferric hydroxide, $Fe(OH)_3$. These hydroxides undergo transformation with the formation of the oxides FeO and Fe_2O_3 with water of crystallization. The composition of rust has been analyzed to vary within the limits indicated by 1 to 3 $FeO \cdot 4$ to $20\ Fe_2O_3 \cdot 22H_2O$. The outer rust portions were found to contain the greatest percentage of ferric iron. Of course, under the surface oxides one will find $Fe(OH)_3$, and under the $Fe(OH)_3$ there will be unoxidized $Fe(OH)_2$ so that a cross section of a rust coating will reveal a gradation of these compounds, and a mass analysis will show a mixture. The presence of carbon dioxide will complicate the compound formation further with the formation of carbonates.

The Importance of Passivity

Most media in the chemical industry are very concentrated and should be very corrosive. It does seem unusual then that such media are handled successfully in equipment constructed from metals and alloys of metals above hydrogen in the electromotive series. The very fact that such metals build up passive films of various kinds makes it possible for the chemical industry to proceed as it has. If it were not for this fact these industries would be impossible to maintain. The use of lead in the sulfuric acid industry, alloys of iron, nickel and chromium in the widest range of corroding media, Durichlor for the chlorides, aluminum for acetic and nitric acids, and many other examples illustrate the dependence of the chemical industry upon passivity.

It is only in the past few years that much emphasis and attention has been given the study of passivity. Today, the study of passivity is one of the most important phases of research into corrosion phenomena. Strangely enough, the rules and factors which control the reactions involving dilute solution corrosion rarely rule over the phenomena involving concentrated solution corrosion. For example, while an increase in carbon content generally points to an indication of accelerated corrosion in most solutions, the opposite case is found to be true when iron is exposed to concentrated nitric or sulfuric acids. Also, the physical state of metal is rarely an important factor in the reactions involving passivity. As previously mentioned, the metals above hydrogen are the only ones which become passive or maintain passive films.

If an oxide film or some other compound film tends to form on the surface of a metal it may be somewhat soluble. If it is dissolved faster than it can form or dissolves at an appreciable rate, it cannot protect the underlying metal. Such films are not passive films, however, if it is formed more readily than it is dissolved, it may act as a protective film. A true passive film must be non-porous and adherent, in addition to being insoluble. Metals which form protective films show a corrosion rate which is logarithmic in type.

TABLE 3

METAL	Medium Passive in	Concentration	Nature of Film
Aluminum	HNO_3	Above 30%	Oxide
Iron	H_2SO_4	78%-98%	Sulfate
Iron	HNO_3	Above 65%	Oxide
Iron	Mixed acid	Less than 20% H_2O	Oxide
Iron	NaOH	Any	Oxide (?)
Lead	H_2SO_4	Under 80%	Sulphate
Magnesium	HF	Conc.	Fluoride
Nickel	NaOH	Any	Oxide (?)
Stainless steels	Various	Various	Oxide
Tin	Various	Dilute	Oxide

Table 3 gives a list of some of the common metals and alloys and the conditions in which they form passive films. The list is not complete but serves to illustrate a few cases.

External Influences

13. *Oxygen concentration.* The importance of oxygen concentration cannot be over emphasized. Too often investigators speak of the presence or absence of oxygen without realizing that the important factor is the concentration of this element.

In those cases of corrosion which are of the hydrogen evolution type, oxygen plays little part. But where hydrogen polarization asserts itself and passive films are possible, oxygen concentration is of the most importance. Those metals which form protective films are subject to two opposing tendencies; one for a protective oxide film to form and prevent further attack, and one for the oxygen to be steadily consumed by the polarized hydrogen and promote attack. Such action can become quite difficult to interpret owing to its sensitivity and dependability upon oxygen differences. With those metals which do not form protective oxide films or in media which have a solvent action on the protective film, attack is generally proportional to the oxygen concentration.

If a piece of iron is placed vertically in a dilute solution of sodium chloride the attack first takes place deep in the solution, while the portion near the air-water line is unattacked. Again, if a drop of water is placed on a piece of iron the attack confines itself at the center of the drop, while the outside ring is unaffected. Deep recesses and crevices in the metal will be more subject to attack than will the surface of the metal. Areas protected by physical objects or by corrosion products, as mentioned above, also prevent the rapid diffusion of oxygen and its attendant protective-film formation. All these cases are dependent upon the existing conditions, which may or may not be susceptible to the influence of oxygen. Where access of oxygen is not hindered a protective film may be encouraged to form or remain; where access of oxygen is inhibited a protective film cannot form and the oxygen acts as the depolarizer of the hydrogen. Figure 3 shows several possible illustrations of differential aeration. Sections marked "P" tend to be pas-

sive and sections marked "A" tend to be anodic and become attacked preferentially.

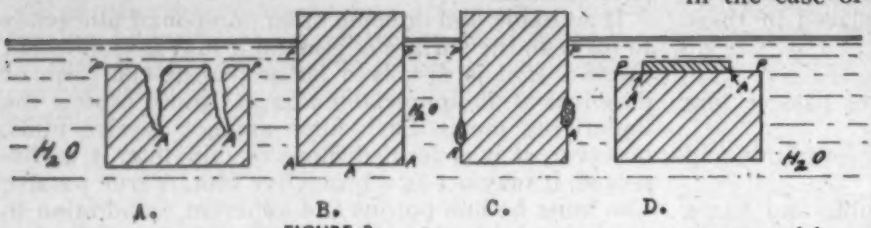


FIGURE 3

14. *Light.* All substances have the property of light absorption to a greater or lesser extent. Since light is a form of energy, the absorbing material must make use of this energy in one way or another. Metals are affected in such a way that their solution potentials are increased, this being one of the explanations of the well-known phenomenon of photo-electricity.

A number of investigations have found that the solution rates and potentials of metals increase in the presence of light. The potential due to the photo-electric effect may be quite small, but with time their influence, in corrosion reaction, may be appreciable. The importance of wave-length has also been emphasized, it being obvious that a shorter wave-length possessing a greater energy content will cause greater corrosion.

15. *Colloids.* The influence of colloids on corrosion should not be mysterious. Colloids may act in such a way that they are absorbed on the surface of the metal, or they may act to increase the viscosity of the solution. In the former case an adherent, protective film may form; in the latter case the flow of ions naturally will be hindered. It is interesting to note that the addition of almost any colloid inhibits corrosion. Many times, in fact, such additions are called inhibitors. A good example of inhibitor action occurs when a little waterglass is added to sodium hydroxide solution. This solution has very little effect on aluminum while the action of hydroxide alone on aluminum is very vigorous.

16. *Bacteria.* Certain micro-organisms are known to influence corrosion considerably, the action on iron being most pronounced. These organisms are known as leptrothrix ochracia, beggiatoa alba, crenothrix polyspora, zallionella ferruginia, sporovibrio desulfuricans, and some other tongue twisters. They may affect corrosion:

1. By changing oxygen concentrations (aerobic forms);

2. By the production of active end-products (sulfate-reducing bacteria); and

3. By the formation of incrustations.

Any aerobic form of life in a medium will naturally decrease the oxygen concentration of that medium. This change may influence corrosion as discussed under 13. Active end-products may be formed, such as humic acids or sulfides. These products will, in turn, affect corrosion as previously outlined. Other organisms may collect at the metal interface and form incrustations or films of themselves or their end-products. These films will influence the oxygen concentration to create oxygen concentration cells.

It is also believed that certain bacteria actually consume metals, but it is more likely that the source is a secondary action. The metal is probably converted to an oxide, hydroxide, or sulfide and then metabolized by the organism.

17. *Cathodic Metals.* When more noble metals, other than impurities or precipitated metals, are present with another metal in a medium, corrosion takes place at the expense of the less noble metal exactly as in the case of local action. The difference between local action and the presence of two dissimilar metals resides only in the greater electrical resistance between the two bodies in the latter case. The conductivity of the medium is, then, the factor determining how great this influence shall be. It is obvious that if an iron and a copper strip are separated by a millimeter the iron will be more subject to corrosion than if they had been separated by an inch.

It is very poor practice, though a common one, and done every day, to fabricate equipment out of dissimilar metals and then employ that equipment in the presence of corroding media.

The case is well known of the Sea Call, a private ship, constructed on the eastern coast which had a Monel metal hull and various steel fixtures such as the rudder and propeller. Exposure to the salt water encouraged electrochemical action to attack the less noble steel, and the ship was never sailed.

18. *Stray Currents.* Corrosion sometimes results from leakage of industrial alternating or direct currents. These currents are called stray currents (vagabundierende strome). When, through poor insulation or for other reasons, electric currents have leaked from power lines such as electric railways, they constitute a potential menace to buried metallic bodies, like gas and water mains, as well as to the power circuit itself.

If the current is direct the flow of the electrons will be from anode to cathode; that is, corrosion will take place where the electrons are leaving. Corrosion will then take place where the electrons are leaving the main power circuit and where they leave the buried metallic conductors. Figure 4 demonstrates this state.

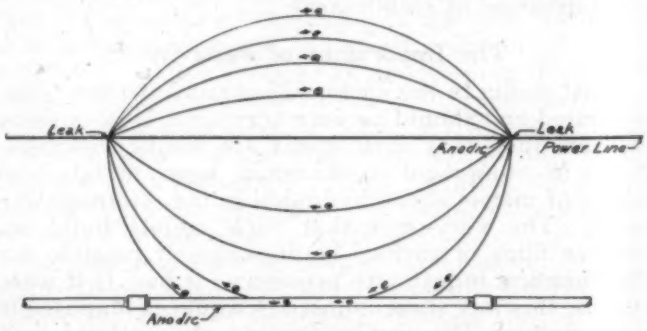


FIGURE 4

In the case of stray alternating currents the situation is more complicated, but the theory is the same. The reversal of current tends to redeposit the dissolved metal; hence corrosion is not always so severe as in direct-current electrolysis. Theoretically, all the metal which has gone into solution should be redeposited on the next reversal of current; actually, however, this does not take place. Electroplating and electro-refining experts are well acquainted with the fact that with metals above hydrogen, normal anodic reactions are generally more complete, according to Faraday's laws, than normal cathodic reactions. Since this is true, each time a point is anodic more metal will go into solution (corrode) than will re-deposit when the metal is cathodic, the result is a steady solution of the metal at two points instead of solution of the metal at one point.

Part 3 will appear in an early issue.

Investigation of Stress in Circular Rings

ALEXANDER SAMOILOFF

IT IS well recognized that for the investigation of stress in any structural member, a convenient graphical method for recording results is of great assistance. Moment diagrams and shear diagrams for beams are extensively used by engineers. The following method, especially developed for the investigation of stress in a circular ring is explained by an illustration of a simple case. A circular ring of a negligible weight is subjected to one outside force *W* acting in the plane of the ring in radial direction as shown in Figure 1. The ring is not restrained and is supported by a number of equidistant supports along its entire circumference. (Supports are not shown.) Figure 1 represents the moment diagram for the ring caused by force *W*. The circle drawn is the axis of the ring as well as a base circle or a circle of zero moment. The values of the moment at various sections of the ring are laid off along the radial lines from this base circle. The positive values are laid off outwardly from the base circle or in the direction away from the center of the circle. The negative values are laid off inwardly or in the direction toward the center at the base circle. A positive moment causes compression in the outer fiber of the ring, and tends to make the ring at that section to concave inward. The values of the moment have been laid off at the sections of the ring at 15-degree intervals. The line drawn joining all the points laid off represents the moment line for a ring of a radius equal to one inch and subjected to one outside force equal to one pound. The values of the moment plotted

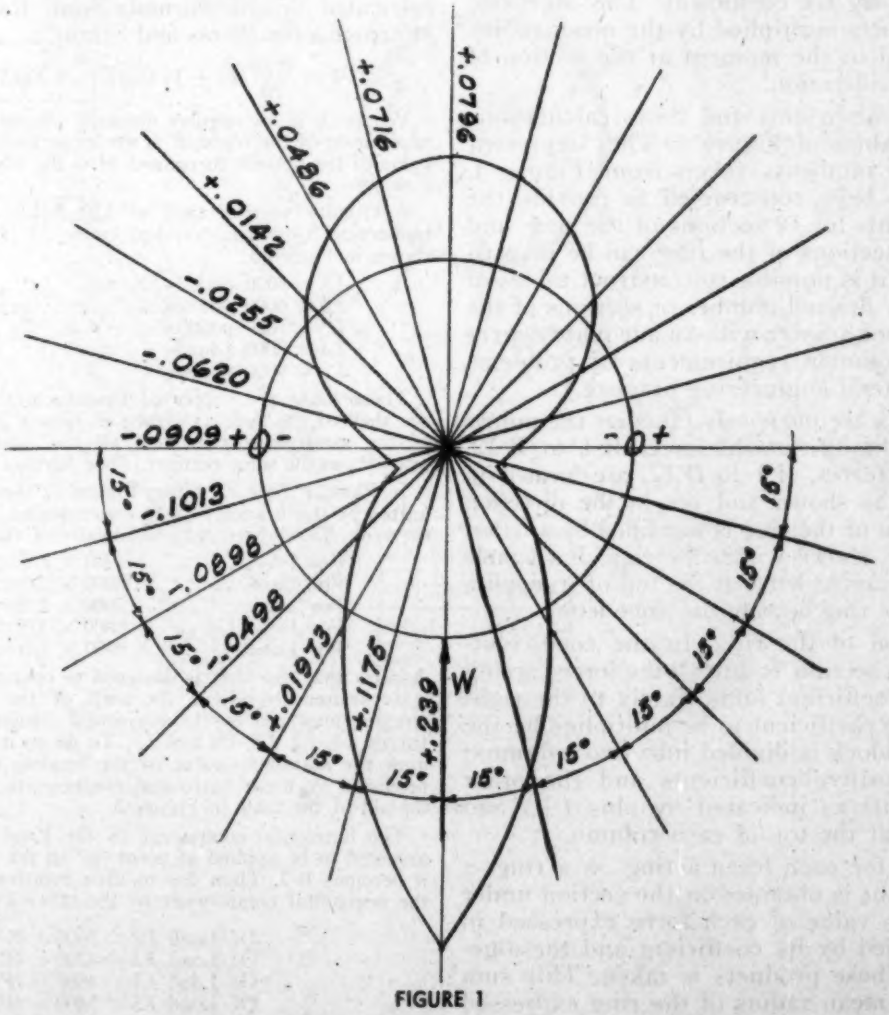


FIGURE 1

are expressed in inch-pounds. To obtain a moment at a given section of a given ring subjected to one given outside force, it is necessary to multiply the value obtained from the moment line in Figure 1 by the value of the mean radius of the ring and by the value of the force expressed in inches and pounds respectively. The resulting value of the moment is expressed in inch-pounds.

If the same ring is acted upon by a number of forces, all acting along radial lines in the plane of the ring, it is possible to superimpose the moment lines of Figure 1 and obtain a resultant moment line. To eliminate the considerable amount of work involved in this procedure of direct superimposing, a much simpler method has been developed. (See Figure 2.)

Conditions of the problem are as follows:

1. All the outside forces are concentrated and act in the plane of the ring.
2. The lines of action of all the outside forces are the radial lines emanating from the center of the ring.
3. The ring is not restrained and is supported along its circumference by a number of equidistant simple supports.

The method of summation is used for determination of a value of the moment at a given section of the ring similar to a method used for determination of a value of the moment at a section of a simply-supported beam subjected to a load of a number of concentrated forces applied at various points of the beam. In case of a beam, each force on one side of the section under consideration is multiplied by its distance from the section and the algebraic sum of these products is equal to a moment at the section. In the case of a ring, each one of the forces acting on the ring is multiplied by its coefficient. The algebraic sum of these products multiplied by the mean radius of the ring is equal to the moment at the section of the ring under consideration.

The necessary coefficients for these calculations are given in the tables of Figure 2. They represent the values of the moments taken from Figure 1. These tables have been constructed to provide the necessary coefficients for 12 sections of the ring, and therefore only 12 sections of the ring can be investigated. (Naturally, it is possible to construct tables of coefficients for any desired number of sections of the ring. Twelve sections answer with an adequate degree of accuracy the common requirements of problems encountered in general engineering practice.)

These 12 sections are purposely taken at the points of application of the 12 outside forces *W*1 to *W*12. These 12 separate forces, *W*1 to *W*12, are located in relation to a ring as shown and act in the direction shown. Each section of the ring is identified by a letter, "*a*" to "*l*" inclusive, shown within the ring. Each table block identified by capital letter at the top of it, applies to the section of the ring bearing the same letter.

Take any section of the ring. In the coefficient-table block for this section, locate all the forces acting on the ring. The coefficient immediately to the right of each force is the coefficient to be multiplied by the force. Each table block is divided into two columns; one containing positive coefficients and the other negative coefficients as indicated by plus (+) and minus (—) signs at the top of each column.

In this manner for each force acting on a ring, a necessary coefficient is obtained at the section under consideration. The value of each force expressed in pounds is multiplied by its coefficient and the algebraic sum of all these products is taken. This sum multiplied by the mean radius of the ring expressed in inches is equal to the moment at a section of the ring under consideration. This moment is expressed in inch-pounds. It should be mentioned that the coefficients shown in the table blocks can be used for the problems involving forces acting in the direction opposite to the one shown in Figure 2. If a force is acting in the direction opposite to the direction shown in Figure 2, it is only necessary to reverse the sign of its coefficients taken from the table blocks at each of the 12 sections of the ring, "*a*" to "*l*" inclusive. Having determined the values of the moment at 12 sections of the ring, the value of the maximum moment is found.

The set of tables shown in Figure 2 is primarily constructed for the solution of problems where all the forces are applied to a ring at angular spacing of 30 degrees or multiples of 30 degrees. It is possible to use these tables for solutions of problems involving several forces located at an angular spacing of 30 degrees and its multiple and several forces located at a different angular spacing. This type of problem is solved in two steps. The first step consists in solving for the moment diagram using the table in Figure 2 for all the forces spaced at 30 degrees of angular spacing and the moment diagram for these forces only is drawn using the same system of co-ordinates as used for the moment diagram in Figure 1. The second step consists of superimposing on the moment diagram obtained in the first step, the moment diagram of the remaining forces individually using the moment diagram shown in Figure 1 for each force.

The moment diagram shown in Figure 1 and the table of coefficients shown in Figure 2 have been calculated by this formula from Raymond J. Roark's "Formulas for Stress and Strain":

$$M = \frac{WR}{2\pi}(1 + \tfrac{1}{2}\,Cos X - \pi\,Sin X + X\,Sin X)$$

Where X is an angular distance measured from the point of application of the force, R is the mean radius of a ring, W is the value of the outside force, and M is the moment.

Example

A circular vertical tank of 120 inches of mean diameter is supporting 5 external vertical loads, *L*1, *L*2, *L*3, *L*4 and *L*5 as shown in Figure 3.

*L*1 = 5000 pounds
*L*2 = 6000 pounds
*L*3 = 7000 pounds
*L*4 = 8000 pounds
*L*5 = 9000 pounds

These loads are supported by structural brackets attached to the shell of the tank as shown in Figure 3. All the brackets are of the same dimensions and all the loads are applied to the brackets in the same manner. (See Section "BB" Figure 3.)

In Plane *Y* (see Elevation Figure 3) the external forces transmitted by the brackets exert concentrated forces on the shell of the tank. The horizontal components of these forces are:

For Load *L*1	5000 × 3/5 = 3000 pounds
For Load *L*2	6000 × 3/5 = 3600 pounds
For Load *L*3	7000 × 3/5 = 4200 pounds
For Load *L*4	8000 × 3/5 = 4800 pounds
For Load *L*5	9000 × 3/5 = 5400 pounds

Assume that the tank is designed to operate at full vacuum and it is desired to relieve the shell of the tank entirely of the stresses produced by the horizontal components of the external forces *L*1, *L*2, *L*3, *L*4 and *L*5. To do so it is necessary to determine the maximum value of the bending moment in a stiffener produced by these horizontal components. It can be done with the aid of the table in Figure 2.

The horizontal component of the Load *L*1 = 3000 pounds is assumed to be applied at point "g" in the table of Figure 2 and it becomes *W*7. Then due to their relative points of application the horizontal components of the other external loads become:

Of Load *L*2 = 3600 = *W*9
Of Load *L*3 = 4200 = *W*11
Of Load *L*4 = 4800 = *W*1
Of Load *L*5 = 5400 = *W*3

At Point "a"	Positive	Negative
Moment produced by force		
$W1 =$	$.239 \times 4800R = 1148R$	
$W3 =$		$.09 \times 5400R = 486R$
$W7 =$	$.680 \times 3000R = 240R$	
$W9 =$		$.026 \times 3600R = 93.6R$
$W11 =$		$.09 \times 4200R = 378R$
	$+ 1388R$	$- 957.6R$

Total Moment $+ 1388R$
$- 957.6R$
$+ 430.4R$ at point "a"

At Point "b"	Positive	Negative
Moment produced by force		
$W1 =$	$.02 \times 4800R = 96R$	
$W3 =$	$.02 \times 5400R = 108R$	
$W7 =$	$.049 \times 3000R = 147R$	
$W9 =$	$.049 \times 3600R = 176.5R$	
$W11 =$		$.091 \times 4200R = 382R$
	$+ 527.5R$	$- 382R$

Total Moment $+ 527.5R$
$- 382.0R$
$+ 145.5R$ at Point "b"

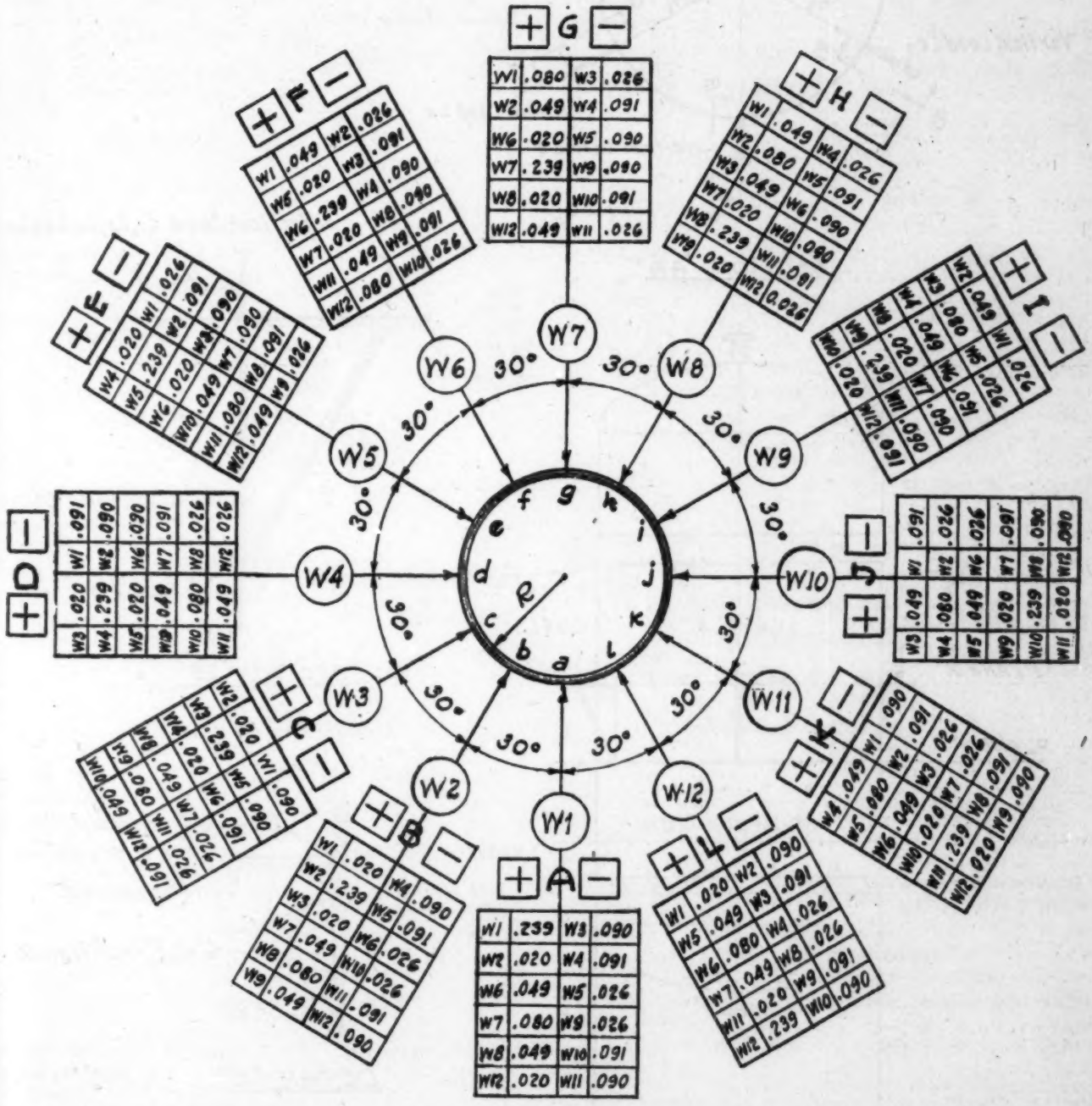


FIGURE 2

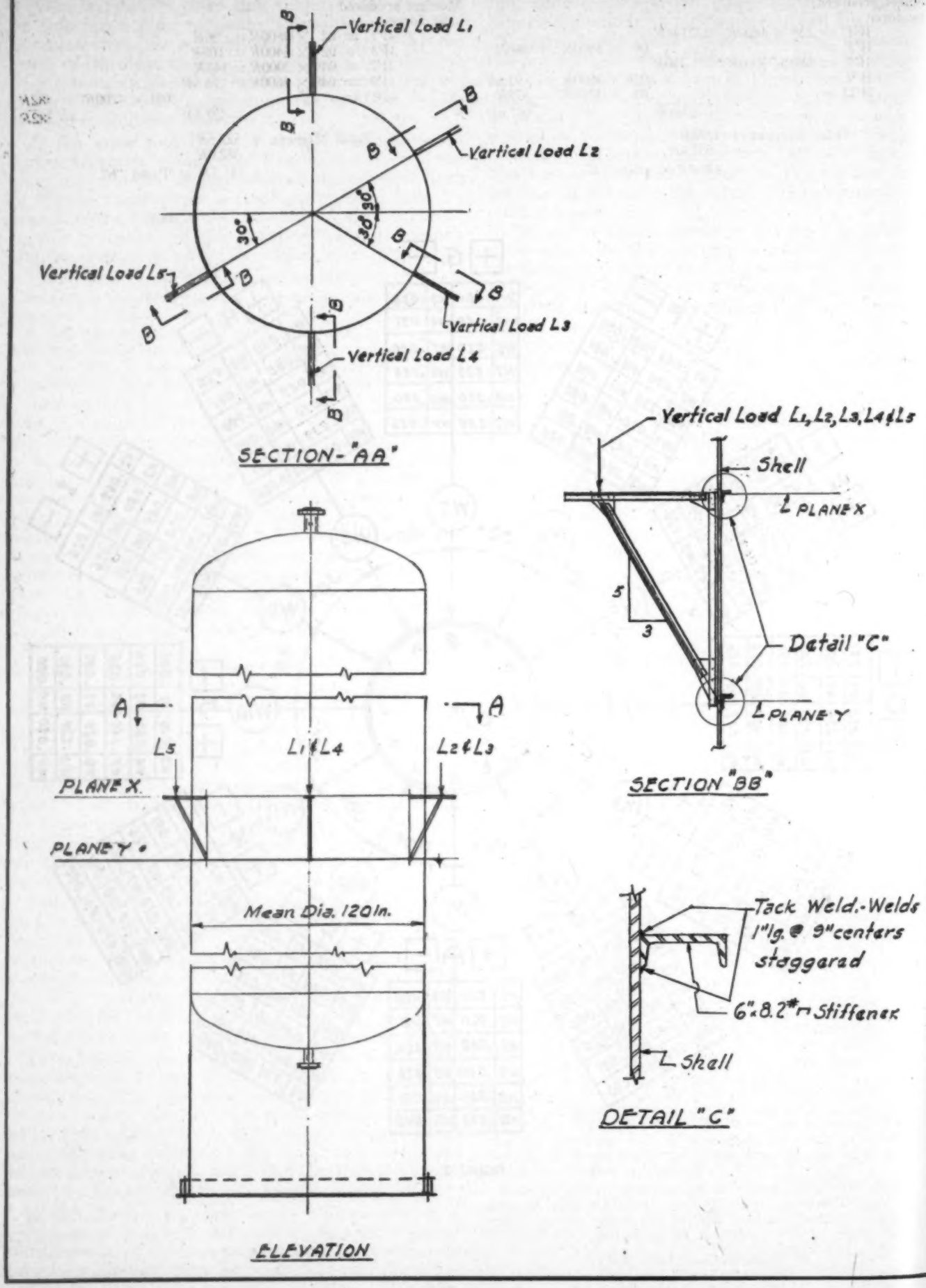

Vertical Load L1
Vertical Load L2
Vertical Load L5
Vertical Load L3
Vertical Load L4
30°
30°
B
SECTION-"AA"
Vertical Load L1, L2, L3, L4 & L5
Shell
℄ PLANE X
5
3
Detail "C"
℄ PLANE Y
SECTION "BB"
A
L5
L1 & L4
L2 & L3
PLANE X
PLANE Y
Mean Dia. 120 In.
ELEVATION
Tack Weld.-Welds 1" lg. @ 9" centers staggared
6" x 8.2# ⊓ Stiffener
℄ Shell
DETAIL "C"

FIGURE 3

At Point "c" — Positive — Negative

Moment produced by force

$W1 = \quad\quad .09 \times 4800R = 432R$

$W3 = .239 \times 5400R = 1290R$

$W7 = \quad\quad .026 \times 3000R = 78R$

$W9 = .080 \times 3600R = 288R$

$W11 = \quad\quad .026 \times 4200R = 109.2R$

$+1578R \quad\quad -619.2R$

Total Moment $+ 1578R$

$- 619.2R$

$+ 958.8R$ at Point "c"

At Point "d" — Positive — Negative

Moment produced by force

$W1 = \quad\quad .091 \times 4800R = 437R$

$W3 = .020 \times 5400R = 108R$

$W7 = \quad\quad .091 \times 3000R = 273R$

$W9 = .049 \times 3600R = 176.5R$

$W11 = .049 \times 4200R = 206R$

$+490.5R \quad\quad -710R$

Total Moment $-710R$

$+490.5R$

$-219.5R$ at Point "d"

At Point "e" — Positive — Negative

Moment produced by force

$W1 = \quad\quad .026 \times 4800R = 125R$

$W3 = \quad\quad .090 \times 5400R = 486R$

$W7 = \quad\quad .090 \times 3000R = 270R$

$W9 = \quad\quad .026 \times 3600R = 93.6R$

$W11 = .080 \times 4200R = 336R$

$+336R \quad\quad -974.6R$

Total Moment $-974.6R$

$+336R$

$-638.6R$ at Point "e"

At Point "f" — Positive — Negative

Moment produced by force

$W1 = .049 \times 4800R = 235R$

$W3 = \quad\quad .091 \times 5400R = 492R$

$W7 = .020 \times 3000R = 60R$

$W9 = \quad\quad .091 \times 3600R = 328R$

$W11 = .049 \times 4200R = 206R$

$+501R \quad\quad -820R$

Total Moment $-820R$

$+501R$

$-319R$ at Point "f"

At Point "g" — Positive — Negative

Moment produced by force

$W1 = .08 \times 4800R = 384R$

$W3 = \quad\quad .026 \times 5400R = 141.5R$

$W7 = .239 \times 3000R = 717R$

$W9 = \quad\quad .09 \times 3600R = 324R$

$W11 = \quad\quad .026 \times 4200R = 109R$

$+1101R \quad\quad -574.5R$

Total Moment $+1101R$

$-574.5R$

$+526.5R$ at Point "g"

At Point "h" — Positive — Negative

Moment produced by force

$W1 = .049 \times 4800R = 235R$

$W3 = .049 \times 5400R = 265R$

$W7 = .020 \times 3000R = 60R$

$W9 = .020 \times 3600R = 72R$

$W11 = \quad\quad .091 \times 4200 = 382R$

$+632R \quad\quad -382R$

Total Moment $+632R$

$-382R$

$+250R$ at Point "h"

At Point "i" — Positive — Negative

Moment produced by force

$W1 = \quad\quad .026 \times 4800R = 125R$

$W3 = .080 \times 5400R = 432R$

$W7 = \quad\quad .090 \times 3000R = 270R$

$W9 = .239 \times 3600R = 860R$

$W11 = \quad\quad .090 \times 4200R = 378R$

$+1292R \quad\quad -773R$

Total Moment $+1292R$

$-773R$

$+519R$ at Point "i"

At Point "j" — Positive — Negative

Moment produced by force

$W1 = \quad\quad .091 \times 4800R = 437R$

$W3 = .049 \times 5400R = 265R$

$W7 = \quad\quad .091 \times 3000R = 273R$

$W9 = .020 \times 3600R = 72R$

$W11 = .020 \times 4200R = 84R$

$+421R \quad\quad -710R$

Total Moment $-710R$

$+421R$

$-289R$ at Point "j"

At Point "k" — Positive — Negative

Moment produced by force

$W1 = \quad\quad .090 \times 4800R = 432R$

$W3 = \quad\quad .026 \times 5400R = 140.5R$

$W7 = \quad\quad .026 \times 3000R = 78R$

$W9 = \quad\quad .090 \times 3600R = 324R$

$W11 = .239 \times 4200R = 1005R$

$+1005R \quad\quad -974.5R$

Total Moment $+1005R$

$-974.5R$

$+30.5R$ at Point "k"

At Point "l" — Positive — Negative

Moment produced by force

$W1 = .020 \times 4800R = 96R$

$W3 = \quad\quad .091 \times 5400R = 492R$

$W7 = .049 \times 3000R = 147R$

$W9 = \quad\quad .091 \times 3600R = 328R$

$W11 = .020 \times 4200R = 84R$

$+327R \quad\quad -820R$

Total Moment $-820R$

$+327R$

$-493R$ at Point "l"

The examination of the total moments at points of the ring from "a" to "l" indicates that the maximum moment occurs at Point "c." It is equal to 958.8R or $958.8 \times 60 = 57{,}528$ inch-pounds.

Assuming that the stiffener is fabricated of a material of maximum allowable stress of 13,750 psi, the section modulus of the stiffener should be:

$$S = \frac{57{,}528}{13{,}750}\ \text{in.}^3 = 4.13\ \text{in.}^3$$

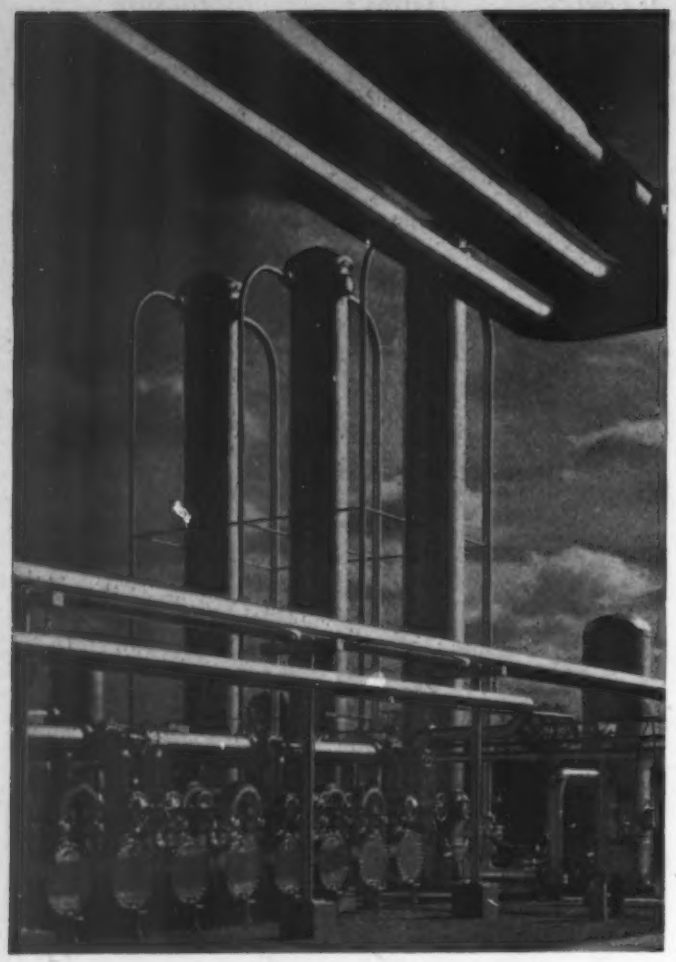
6" @ 8.2# structural channel has section modulus equal to 4.3 in.^3 and is adequate.

It is attached to the shell of the tank as shown in Figure 4 Detail "C."

If it is desired also to place another stiffener to relieve the shell of stresses produced by the external loads in Plane X this can be done very simply. Since the horizontal components of each external force in Plane Y and X are equal, the maximum bending moments produced by the external forces in Plane X and Plane Y are also equal, although the opposite sign, which is immaterial.

Consequently the stiffener in Plane X should have the same section modulus as the one in Plane Y, provided the maximum allowable stress is the same.

For this reason 6" @ 8.2# channel stiffener is placed in Plane X as well as in Plane Y.



Absorbers in The Chicago Corporation's Plant at Carthage, Texas

Calculated Theoretical Increase in Propane Absorption by Lowering Lean Oil Molecular Weight

R. M. STEWART and A. M. HEGWER*
The Chicago Corporation

RECENT trends in the use of propane as a substitute for butane in liquefied petroleum gas and as a raw material in the chemical-conversion and petrochemical industries has caused the natural gasoline manufacturer to consider methods by which he may increase propane recovery. It is, therefore, appropriate to consider methods by which propane recovery may be increased with existing plant equipment.

An inspection of the absorption factor equation

$$A = \frac{L}{KV} \qquad (1)$$

where
A = absorption factor
L = mols liquid entering absorber
V = mols vapor entering absorber
K = equilibrium constant for constituent being considered

makes it obvious that an increase in the molal oil-gas ratio will cause a consequent increase in the absorption factor, A, and therefore an increase in the absorption of the component being considered. An increase in the molal oil-gas ratio may be obtained by the use of a lower molecular weight absorption oil. A summary of the calculations made to show the increase in propane and butane recovery as the molecular weight of the absorption oil is lowered is presented in Table 1.

These calculations were made using an absorption oil of the same gravity but different molecular weights to show the increase in propane absorption as the molecular weight is decreased from 240 to 180.

* Mr. Hegwer is now connected with McCarthy Chemical Company.

No effort was made to calculate the absorption oil loss through retrograde vaporization, as this condition may be in part eliminated by use of narrower boiling range oils. A constant flow of gas and absorption oil to absorbers of 8 theoretical plates and operating at 1000 psia was assumed in each case. In each of the four cases calculated the effective plate temperatures throughout the absorbers was considered constant at 85° F., changes in heat of absorption being considered negligible for the purpose of these calculations.

The method for predicting the performance of absorption columns as developed by Horton and Franklin[2] was used in these calculations. This method uses the absorption factor relationships as presented by Souders and Brown,[1] but the absorption factor, A, is selected in terms of an effective plate.

The fundamental relationship is as follows:

$$\frac{Y_{n+1} - Y_1}{Y_{n+1} - Y_o} = \frac{A^{n+1} - A}{A^{n+1} - 1} \qquad (2)$$

in which
A = Absorption factor
Y_{n+1} = Mols of constituent in vapor entering absorber per mol total vapor entering absorber
Y_1 = Mols of constituent leaving per mol total vapor entering absorber
Y_o = Mols of constituent entering absorber in lean oil per mol of total vapor entering absorber

Table 3 presents a sample calculation of the composition of lean gas for the absorber being considered. The information required to make the calculations may be listed as follows:

1. The rich gas composition, Table 1.
2. The molal oil-gas ratio, Table 1.
3. Table of m/n or ratio of effective plate number

TABLE 1

Effect of Molecular Weight on Absorption

	RICH GAS				CASE I				CASE II				CASE III				CASE IV			
	Mol Percent	M Cu. Ft. Day	Mols Day	Bbls. Day	Percent Absorbed	Mol Fraction Absorbed	Mol Fraction Lean Gas	Lean Gas Mol Percent	Percent Absorbed	Mol Fraction Absorbed	Mol Fraction Lean Gas	Lean Gas Mol Percent	Percent Absorbed	Mol Fraction Absorbed	Mol Fraction Lean Gas	Lean Gas Mol Percent	Percent Absorbed	Mol Fraction Absorbed	Mol Fraction Lean Gas	Lean Gas Mol Percent
Methane	93.05	93,050	245,324	....	3.82	0.0355	0.8952	95.42	3.51	0.0327	0.8980	95.31	3.25	0.0303	0.9004	95.19	2.47	0.0276	0.9031	95.08
Ethane	4.38	4,380	11,540	....	18.59	0.0081	0.0357	3.81	17.18	0.0075	0.0363	3.85	15.69	0.0068	0.0370	3.91	14.48	0.0063	0.0375	3.95
Propane	1.26	1,260	3,320	823	47.57	0.0060	0.0066	0.70	43.95	0.0055	0.0071	0.75	40.15	0.0051	0.0075	0.79	37.05	0.0047	0.0079	0.83
iso-Butane	0.30	300	790	233	85.70	0.0025	0.0005	0.05	81.20	0.0024	0.0006	0.06	76.80	0.0023	0.0007	0.07	69.20	0.0021	0.0009	0.09
n-Butane	0.38	380	1,001	285	96.90	0.0036	0.0002	0.02	93.80	0.0035	0.0003	0.03	91.10	0.0034	0.0004	0.04	86.80	0.0033	0.0005	0.05
iso-Pentane	0.17	170	448	148	100.00	0.0017	.....	0.0	100.00	0.0017	.....	0.0	100.00	0.0017	.....	0.0	100.00	0.0017	.....	0.0
n-Pentane	0.12	120	316	103	100.00	0.0012	.....	0.0	100.00	0.0012	.....	0.0	100.00	0.0012	.....	0.0	100.00	0.0012	.....	0.0
Hexane	0.32	320	844	312	100.00	0.0032	.....	0.0	100.00	0.0032	.....	0.0	100.00	0.0032	.....	0.0	100.00	0.0032	.....	0.0
Total	100.00	100,000	263,583	1904		0.0618	0.9382	100.00		0.0577	0.9423	100.00		0.0540	0.9460	100.00		0.0501	0.9499	100.00
No. of Theoretical Trays						8				8				8				8		
Absorber Pressure, psia						1000				1000				1000				1000		
Effective Plate Temperature, °F						85				85				85				85		
Lean Oil Rate, GPM						500				500				500				500		
Lean Oil Gravity, °API						39.0				39.0				39.0				39.0		
Lean Oil Molecular Weight						180				200				220				240		
Characterization Factor, K						11.69				11.84				11.98				12.10		
Gals. Lean Oil per Mol						26.05				28.94				31.84				34.73		
Mols Lean Oil per Day						27,639				24,879				22,613				20,731		
Mols Lean Oil per Mol Rich Gas						0.1049				0.0944				0.0858				0.0787		
Propane:																				
Bbls. Absorbed per Day						394				361				335				308		
Increase, Bbls./Day						86				53				27				0		
Increase, Percent						27.92				17.21				8.77				...		
iso-Butane:																				
Bbls. Absorbed per Day						196				189				181				167		
Increase, Bbls./Day						29				22				14				0		
Increase, Percent						17.37				17.17				8.38				...		
n-Butane:																				
Bbls. Absorbed per Day						271				264				257				249		
Increase, Bbls./Day						22				15				8				0		
Increase, Percent						8.84				6.02				3.21				...		

to total number of plates vs. effective absorption factors, Table 2

4. The number of theoretical plates, assumed as 8
5. Empirical equation from Horton-Franklin[2]

$$V_m = V_1 \left(\frac{n+1-m}{n} \right) \quad (3)$$

in which

V_m = Total mols vapor on effective plate m
V_1 = Total mols lean vapor leaving absorber
n = Number theoretical plates in absorber
m = Number for the effective plate for a constituent counting from top plate = 1, and bottom plate = n

$$V_{m+1} = \frac{V_m}{\left(\frac{V_1}{V_{n+1}} \right)^{\frac{1}{n}}} \quad (4)$$

in which V_{n+1} = mols rich gas and used as one

By material balance

$$L_m = L_o + V_{m+1} - V_1 \quad (5)$$

in which L_m = Total mols of liquid on effective plate
L_o = Mols lean oil

In calculating absorber performance by the Horton Franklin[2] method, it is first necessary to assume the number of mols of gas absorbed per mol of rich gas entering. This assumed value is used in obtaining V_1. Calculations must then be made to obtain $Y_{n+1} - Y_1$, which value must be approximately equal to the assumed figure, adjustment being made by trial and error until $Y_{n+1} - Y_1$ equals the assumed mol fraction of gas absorbed. In the case of sample calculations shown in Table 3, 0.0617 mols of gas absorbed per mol of rich gas was assumed. In sample calculations shown in Table 3:

Column 1, given
Column 2, assumed, based on experience in calculations and Table 2
Column 3, calculated from Column 2 and n = 8
Column 4, calculated from Equation 3 and Column 3
Column 5, calculated from Equation 4 and Column 4
Column 6, calculated from Equation 5, Column 5 and 0.1049 mols lean oil
Column 7, equilibrium constants[3,4] for pressure of 1000 psia and 85° F.
Column 8, calculated from Columns 4, 6 and 7

$$A = \frac{L}{KV}$$

Column 9, from absorption factor plot[1] for values of A and 8 theoretical plates
Column 10, Column 9 times Column 1
Column 11, Column 1 minus Column 10
Column 12, mol fraction of each component in lean gas divided by mol fraction of lean gas times 100

Similar calculations were made using 200, 220, and 240 molecular weight absorption oil with results shown in Table 1.

By inspection of Table 1 it may be seen that for the problem under consideration a reduction of absorption oil molecular weight from 240, as shown in Case IV, to 220, in Case III, will give a theoretical increase in propane absorption of 27 barrels per day or 8.77 percent increase; and that a further lowering of molecular weight to 200, shown under Case II, will increase propane absorption to 17.21 percent increase or 53 barrels per day. However, the greatest overall increase in propane absorption for the four cases calculated occurs with 180 molecular weight absorption oil which yields a theoretical increase of 86 barrels per day or 27.92 percent increase.

Although the original purpose of these calculations

* Now with McCarthy Chemical Company

TABLE 2

Location of Effective Absorption Factors[2]

A	m/n*
0—0.1	1.0
0.1—0.4	0.9
0.4—1.0	0.8
1.0—4.0	0.7
Above 4.0	0.6

*m = Plate corresponding to effective factor; n = total theoretical plates.

TABLE 3

Sample Calculation of Absorption Efficiencies

Assumed Absorption—0.0617 mols per mole rich gas

	1	2	3	4	5	6	7	8	9	10	11	12
	Mol Fraction	m/n	m for n=8	V_m	V_{m+1}	L_m	$K_{1000\ psia\ @\ 8\ °F}$	A_{eff}	$\frac{Y_{n+1}-Y_1}{Y_{n+1}}$	$Y_{n+1}-Y_1$	Y_1	Y_1 Mol Percent
Methane	0.9307	1.0	8.0	0.9921	1.0000	0.1666	4.40	0.0382	0.0382	0.0355	0.8952	95.42
Ethane	0.0438	0.9	7.2	0.9857	0.9935	0.1601	0.87	0.1859	0.1859	0.0081	0.0357	3.81
Propane	0.0126	0.9	7.2	0.9857	0.9935	0.1601	0.34	0.4757	0.4757	0.0060	0.0066	0.70
iso-Butane	0.0030	0.8	6.4	0.9795	0.9873	0.1539	0.165	0.9524	0.857	0.0025	0.0005	0.05
n-Butane	0.0038	0.8	6.4	0.9795	0.9873	0.1539	0.125	1.257	0.959	0.0036	0.0002	0.02
iso-Pentane	0.0017	0.7	5.6	0.9733	0.9811	0.1477	0.060	2.529	1.000	0.0017	0.0000	0.0
n-Pentane	0.0012	0.7	5.6	0.9733	0.9811	0.1477	0.045	3.37	1.000	0.0012	0.0000	0.0
Hexane	0.0032	0.6	4.8	0.9671	0.9748	0.1414	0.0195	7.50	1.000	0.0032	0.0000	0.0
Total	1.0000									0.0618	0.9382	100.00

was to investigate the theoretical increase in propane absorption by the Horton-Franklin[2] method of calculation, it was felt that the increase in absorption of butanes as compared to that of propane would also be of value. Calculations for the increase in absorption of both iso and normal butane were calculated for each case and are tabulated in Table I.

In Figure 1, absorption oil molecular weight was plotted against percent of component absorbed, taken from Table 1, for propane, iso-butane and normal butane. From this plot it may be seen that the percent of propane absorbed as the molecular weight of absorption oil is lowered is almost a straight line function while that for iso-butane and normal butane tends to rise in a steeper curve at the higher molecular weights but begin to level out as the molecular weight is lowered below 220, which indicates that the greatest increase in the absorption of butanes occurs as the molecular weight of absorption oil is lowered from above 220.

Figure 2 shows a plot of percent increase in production against absorption oil molecular weight for propane, iso-butane and normal butane. These curves further indicate the tendency of iso and normal butane to increase as the molecular weight is lowered to 220 and then to level out as the molecular weight is lowered from that point. It is to be pointed out that the percent increase in iso-butane and propane are almost identical as the molecular weight is lowered from 240 to 220, with separation of the two curves occurring just below this point, after which, separation of the two curves becomes exceedingly more pronounced from that point to the end of the plot.

It should be pointed out that these calculations have been made for one particular problem and that the increase in absorption and production were figured for the flow and gas composition of that case. Although it is felt that many existing plants may increase propane absorption by selective buying of absorption oils or changing present absorption oil fractionating and purifying equipment, it should be given careful study to determine economic feasibility.

REFERENCES

[1] Souders, M., and Brown, G. G. Ind. Eng. Chem. 24, (1932), 517.

[2] Horton, G. H., and Franklin, W. B., Ind. Eng. Chem. 32, (1940), 1384.

[3] Katz, D. L., and Hachmuth, K. H., Ind. Eng. Chem., 29, (1937), 1073.

[4] Webber, C. E., A.I.M.E., 142, (1941), 192.

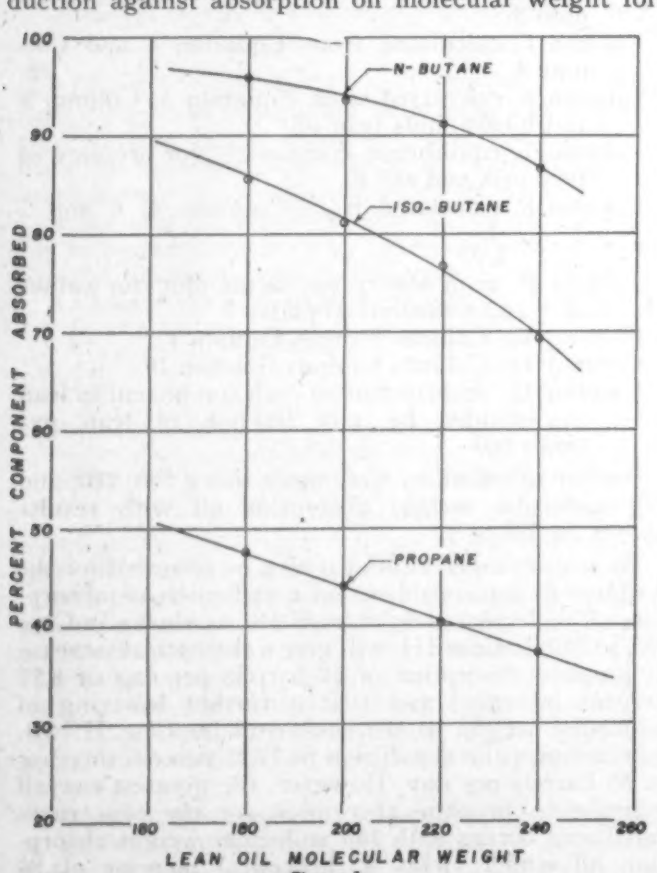


Figure 1.

Effect of Lean Oil Molecular Weight on Absorption.

(Constants—See Table 1)

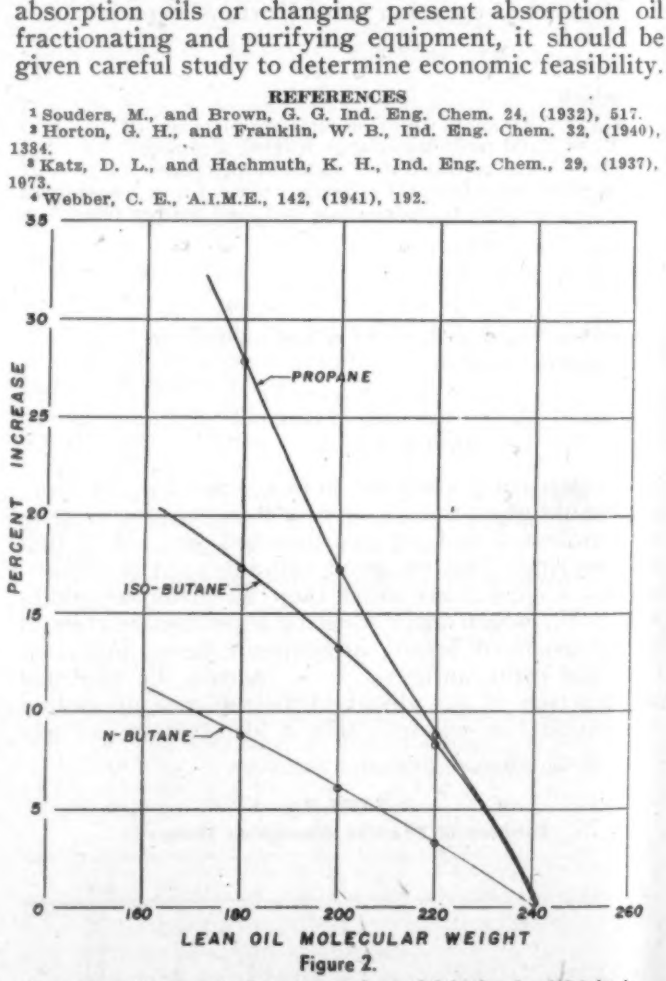


Figure 2.

Percentage Increase in Recovery as Lean Oil Molecular Weight is Lowered from 240.

(Constants—See Table 1)

Calculation of Heat Recovery at Cities Service Refinery with Continuous Blowoff System

M. C. McKEOWN
Cochrane Corporation

THE primary purpose of a continuous blowoff system is to recover heat which would ordinarily be lost when boilers are blown directly to the sewer. In a system employing the flash principle, heat is recovered in two stages:

1. By the utilization of steam flashed from the blowoff.
2. By directing the hot waste water remaining after flash through a heat exchanger.

Advantages of continuous blowoff can be most economically attained through the use of equipment employing the flash principle. With this method of operation, the concentrated boiler water is introduced into a tank operating at any desired pressure, although usually this pressure corresponds to that of the operating pressure of the feedwater heater in the simplest single stage system as indicated in Figure 1.

The Cities Service Oil Company on Petty's Island in the Delaware River between Philadelphia and Camden, N. J., has installed a continuous blowoff system of this type on five boilers. Four of these boilers are 200 hp rating and the fifth is a 35,000 lb./hr. boiler. All are operated at 150 psi which corresponds to 366° F. The four smaller boilers are operated at 150 percent of rating and at 30 lb. per boiler hp, the total steam load amounts to 71,000 lb./hr.

Because the blowoff water is at a temperature (366° F.) corresponding to the pressure at which the boilers are operating, a reduction in the pressure causes flashing and steam is generated at the lower pressure. This steam can be utilized to heat feedwater in an open or deaerating heater or can be condensed in a closed heater or flash condenser, imparting heat to the water at a point beyond the deaerating heater. The unflashed water is generally passed through a heat exchanger, the cooling medium being the makeup water on its way to the boiler.

The installation of a continuous blowoff system recovers practically all of the heat in the blowoff; the only heat wasted is that which corresponds to the thermal difference between the incoming cooling water and the blowoff water going to the sewer.

The amount of blowoff required is, in most instances, determined by the permissible concentration of total solids in the boiler water.

The accompanying table of general limits in permissible concentration of boiler water is recommended by the American Boiler Manufacturing Association and Affiliated Industries.

Boiler Pressure psi	Total Solids ppm
0- 300	3500
301- 450	3000
451- 600	2500
601- 750	2000
751- 900	1500
901-1000	1250
1001-1500	1000

To determine how rapidly the boiler water will concentrate, an analysis of the Delaware River water used as boiler feed is necessary. The accompanying table indicates the probable theoretical combination of the various constituents of the raw water and shows a total of 194.1-ppm dissolved solids.

Theoretical Combinations from Raw Water Analysis

Calcium Carbonate, $CaCO_3$	57.1 — ppm
Magnesium Sulphate, $MgSO_4$	79.2 — ppm
Silica, SiO_2	8.8 — ppm
Iron Oxide and Alumina	5.2 — ppm
Sodium Sulphate, Na_2SO_4	8.2 — ppm
Sodium Chloride, NaCl	35.6 — ppm
Total Dissolved Solids	194.1 — ppm
Organic Matter	9.0 — ppm

In order to demonstrate the procedure used in determining heat recovery and savings, the following conditions at this plant are listed:

1. Five boilers operating at 150 psi with a total evaporation rate of 71,000 lb./hr.
2. Make up water (100 percent) containing approximately 200-ppm total solids.
3. Temperature of makeup is 80° F.
4. Pressure of flash tank operation is 4-psi.

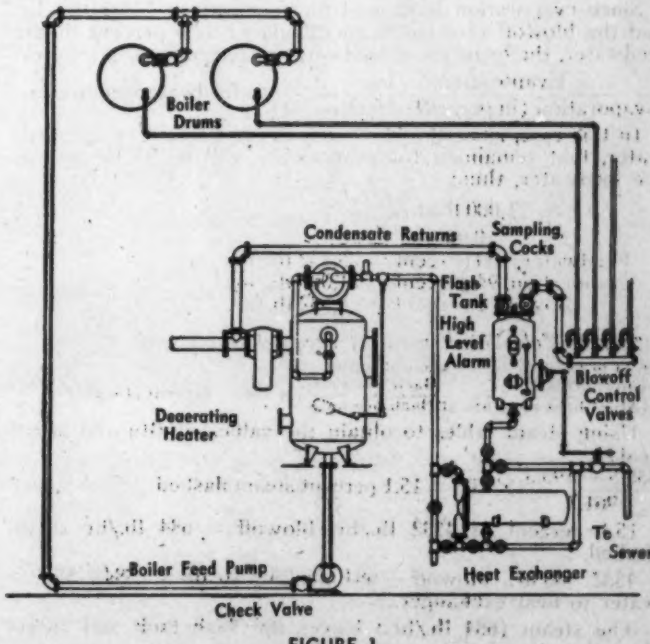


FIGURE 1

Diagram indicating relation of boiler-room equipment to flash tank and heat exchanger at the Petty's Island plant of Cities Service Oil Company.

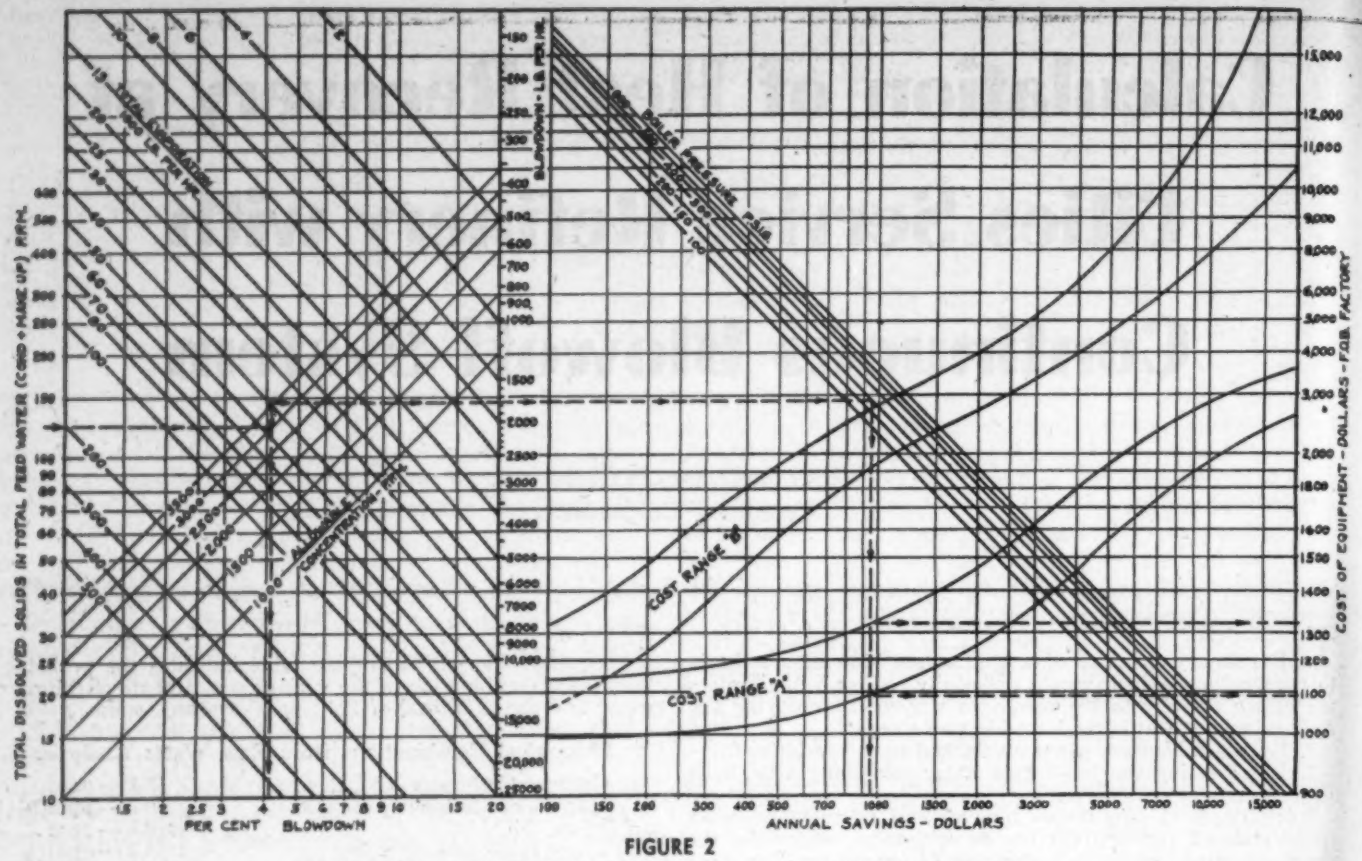

TOTAL DISSOLVED SOLIDS IN TOTAL FEED WATER (COND + MAKE UP) P.P.M.
BLOWDOWN - LB. PER HR.
BOILER PRESSURE P.S.I.
COST RANGE "B"
COST RANGE "A"
COST OF EQUIPMENT - DOLLARS - F.O.B. FACTORY
PER CENT BLOWDOWN
ANNUAL SAVINGS - DOLLARS

FIGURE 2

Chart for estimating savings by, and cost of, continuous blowoff equipment.

Heat Recovery

Step 1—Calculate Percent Blowoff Required

The boiler pressure is 150 psi, therefore, the maximum allowable concentration of total solids is 3500-ppm.

$$\frac{\text{Total dissolved solids in feedwater}}{\text{Permissible total solids in boiler}} \times \text{percent makeup} = \text{blowoff}$$

$$\frac{200 \text{ ppm}}{3500 \text{ ppm}} \times 100 \text{ percent makeup} = 5.7 \text{ percent}$$

(roundoff to 6 percent blowoff).

Step 2—Calculate Quantity of Feedwater Per Hour

Since evaporation is carried on at a rate of 71,000 lb./hr. and the blowoff rate has been calculated as 6 percent of the feedwater, the quantity of feedwater is determined as follows:

$$\frac{\text{Evaporation lb./hr.}}{\text{Evaporation (in percent of feedwater)}} = \text{feedwater required.}$$

In this case, since the blowoff rate is 6 percent of the feedwater, that remaining for evaporation will be 94 percent of the feedwater, thus:

$$\frac{71{,}000 \text{ lb./hr.}}{0.94} = 75{,}532 \text{ lb./hr. feedwater}$$

Feedwater, 100 percent = 75,532 lb./hr.
Evaporation, 94 percent = 71,000 lb./hr.
Blowoff, 6 percent = 4,532 lb./hr.

Step 3—Calculate Percent of Steam Flashed from Blowoff

$$\frac{\text{Heat of liquid at boiler pressure} - \text{Heat of liquid at flash pressure}}{\text{Latent heat of steam at flash pressure}} \times 100 = \text{percent steam}$$

Using steam tables to obtain the values of Btu and latent heat:

$$\frac{338.5 - 193.3}{961.7} \times 100 = 15.1 \text{ percent steam flashed}$$

15.1 percent of 4532 lb./hr. blowoff = 684 lb./hr steam flashed.

4532 lb./hr. blowoff — 684 lb./hr. steam = 3848 lb./hr. water to heat exchanger.

The steam (684 lb./hr.) leaves the flash tank and enters the exhaust main.

The water (3848 lb./hr. at 225° F.) is drained from the flash tank and directed through a heat exchanger.

Step 4—Calculate Amount of Cooling Water Through Heat Exchanger

In heating makeup water to the temperature of the feedwater heater, approximately 15 percent of exhaust steam will be condensed. The cold makeup will, therefore, be 64,202 lb./hr. to which is added sufficient condensed steam during the heating process, so that the boiler feed totals the required 75,532 lb./hr.

Step 5—Calculate the Temperature Rise on the Cooling Water Side of the Heat Exchanger

Assume a terminal difference of 15° F. This means that the blowoff water will go to sewer at 95° F. (15° F. higher than incoming cooling water).

$$\frac{\text{Flash tank drain lb./hr.} \times \text{unflashed blowoff water temperature drop}}{\text{Cooling water lb./hr.}} = \text{Temperature rise}$$

$$\frac{3848 \text{ lb./hr.} \times (225° \text{ F.} - 95° \text{ F.})}{64{,}202 \text{ lb./hr.}} = 7.8° \text{ F. (say } 8° \text{ F.)}$$

Step 6—Savings

The Btu saving is equal to the total heat in the boiler water in excess of the heat content of the cooling water available, if there were no terminal difference in the heat exchanger. However, the terminal difference does represent a waste of heat and must be taken into consideration.

$$\text{Blowoff lb./hr.} \times \left(\text{heat in liquid at boiler pressure} - \text{heat in liquid of incoming makeup}\right) - \left(\text{hot blowoff water to heat exchanger lb./hr.} \times \text{terminal difference of heat exchanger}\right) = \text{Btu./hr. saved}$$

Substituting:

$4532\,(338\text{-}48) - (3848 \times 15) = 1{,}256{,}560$ Btu/hr. saved.

The actual dollar savings per year may be calculated from the following equation. It will be necessary to assume certain conditions:

Plant operation: 24 hr./day for 300 days/year.

Fuel cost: $0.05 per gallon as fired.

Boiler efficiency: 75 percent.

$$\frac{\text{Btu/hr. saved} \times \text{hr. of operation/year} \times \text{oil cost/gal.}}{\text{Btu/gal. oil} \times \text{boiler efficiency}} = \text{Dollars saved.}$$

$$\frac{1{,}256{,}560 \times 7200 \times 0.05}{150{,}000 \times 0.75} = \$4015 \text{ per year.}$$

Thus, at the present day cost of about $1,400.00, this type

of continuous boiler blow off heat recovery equipment pays the Cities Service Oil Company at the rate of approximately 300 percent on its investment. Installed in 1939, and serving since without any appreciable maintenance cost, total savings have surpassed $30,000.00.

Chart for Simplified Saving Estimates

The foregoing information has been charted to eliminate the necessary calculations and provide an accurate estimate of cost for the equipment and the expected dollar savings. Following are directions for use of the accompanying chart:

The left-hand abscissa is the value of the Total Dissolved Solids (TDS) in the feedwater to the boiler including makeup and all condensate returns. Its actual value is found by multiplying the TDS in the raw makeup by the percent of makeup.

Example:

TDS = 125 ppm
Allowable boiler concentration = 3000 ppm
Boiler pressure = 200 psi
Total evaporation = 40,000 lb./hr.

Enter chart at the left at 125 ppm and draw horizontal line to the 3000 ppm Allowable Concentration line. Through this point draw a vertical line to the bottom of the chart and read the percent of blowoff (4.2 percent). Now extend the vertical line (if necessary) until it intersects the proper Total Evaporation Line (40,000 lb./hr.) and draw a horizontal line to the right from this point of intersection to the proper Boiler Pressure (200 psi), reading the total blowoff (1754 lb./hr.) where the line intersects the blowdown column. From the intersection of this line with the proper boiler pressure line, drop a vertical line to the bottom of the chart and read the approximate Annual Savings ($950.00) for operation 24 hours per day, 300 days per year with 75 percent boiler efficiency and 14,000 Btu per pound coal at $5.00 per ton on the grates. (For values other than these multiply the annual savings by the appropriate factor as for instance for 12 hours operation multiply the annual savings by one half.) Where this last line intersects the limits of Cost Range "A" draw two horizontal lines to the right-hand edge of the chart and read the approximate Cost of Equipment ($1090 to $1320) for a one flash tank system. For total evaporations in excess of those covered by the chart, divide the total evaporation by ten and proceed as before multiplying the determined blowoff and annual savings values by 10 for final result. When this procedure is followed, Cost Range "B" is to be used directly without using a factor.

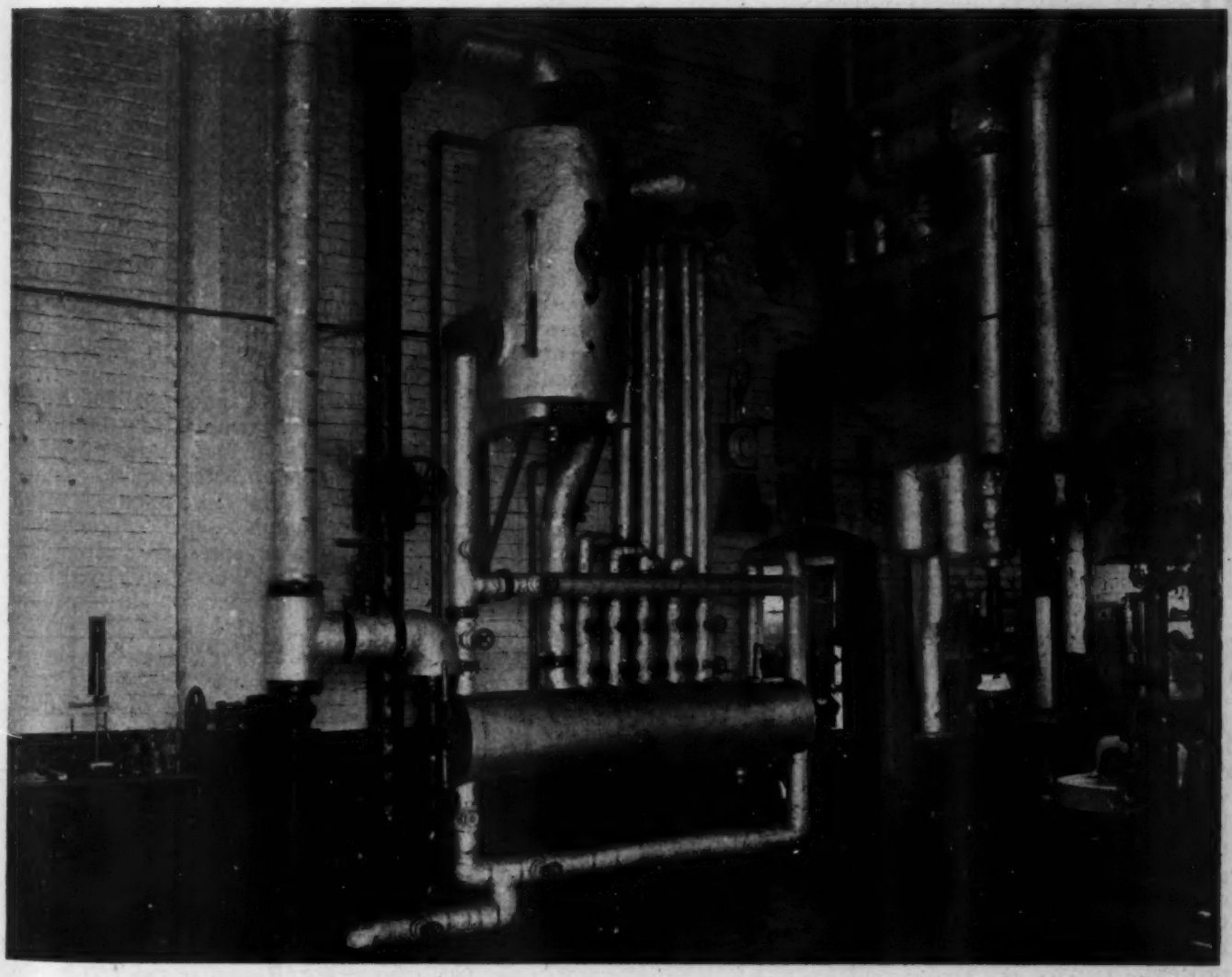


FIGURE 3

Flash tank above and heat exchanger below at the Cities Service Oil Company, Petty's Island, New Jersey, installation of the Cochrane continuous blowoff heat recovery system. Note the five flocontrol valves from the five boilers at left.

Alignment Chart for Calculating Allowable Vapor Velocity In Plate Towers

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By THE method of dimensional analysis it can be shown that the force of frictional resistance to the motion of a droplet in a gas in which the flow is turbulent is

$$F = kD^2U^2\rho_2 f\left(\frac{DU\rho_2}{u}\right)$$

Equating this force to the driving force when the droplet is falling under the influence of gravity, we get

$$bD^3(\rho_1 - \rho_2)g = kD^2U^2\rho_2 f\left(\frac{DU\rho_2}{u}\right)$$

and, on solving for U,

$$U = \sqrt{\frac{bD^3(\rho_1 - \rho_2)g}{kD^2\rho_2 f\left(\frac{DU\rho_2}{u}\right)}}$$

This velocity is independent of time because the formula is derived on the basis of no unbalanced force and, therefore, no acceleration. By restricting its application to the high velocity range in which the Reynolds number function is sensibly constant and by assuming that droplet size is constant the equation may be simplified to:

$$U = K\sqrt{\frac{\rho_1 - \rho_2}{\rho_2}}$$

Actually, of course, the droplet size is not constant. Just above the plate the droplets will be relatively large and farther above they will be smaller. Several investigators have demonstrated that plate columns will operate at high efficiency with a visible spray just above the bubble caps. It has been estimated that 20 percent of the vapor-liquid interaction on a plate takes place in this spray zone. We are concerned with the smaller, more stable droplets. Above the critical velocity these droplets will be carried to the plate above, thereby undoing the distillation process.

For calculating values of U as vapor velocity in feet per second based on the total cross section area of the empty tower, values of K as a function of plate spacing and liquid seal on the plates have been determined by Carey.[1] An alignment chart has been constructed to make possible rapid calculation of U using Carey's values of K.[2]

In the example shown on the chart it is desired to find the allowable vapor velocity in a column having bubble trays on 18-inch centers and having a 3-inch liquid seal on the plates. As can be seen from the table, this gives a K = 0.09. The densities of liquid and vapor calculated for the conditions of operation of the column are 32 pounds per cubic foot and 1.28 pounds per cubic foot, respectively. By connecting 32 on the ρ_1 scale and 1.28 on the ρ_2 scale a point is determined on the pivot line X. Follow the guide lines to get the corresponding point on the pivot line Y. Connect this point and 0.09 on the K scale and read the maximum allowable vapor velocity, 0.44 feet per second, on the U scale.

That this method is safe is shown by Stone[3] who reports that values of U calculated in this way are conservative, being approximately 20 percent below the maximum allowable velocities which were determined experimentally on a butane-isobutane fractionator at 100 psig with a plate spacing of 18 inches.

It will be noticed from the formula that the liquid and vapor densities may be in any units, provided that they both have the same units. If specific gravity is used both liquid and vapor must be referred to the same standard substance. Obviously, the nomograph can be used as easily for a reverse calculation. For example, the allowable liquid and vapor densities could be determined for a given vapor velocity, plate spacing and liquid seal.

A table giving Carey's values for K is conveniently located on the nomograph chart. The liquid seal values are to be understood as height of the liquid above the top of the bubble cap slots. The static seal (from top of weir to top of bubble cap slots) frequently is used.

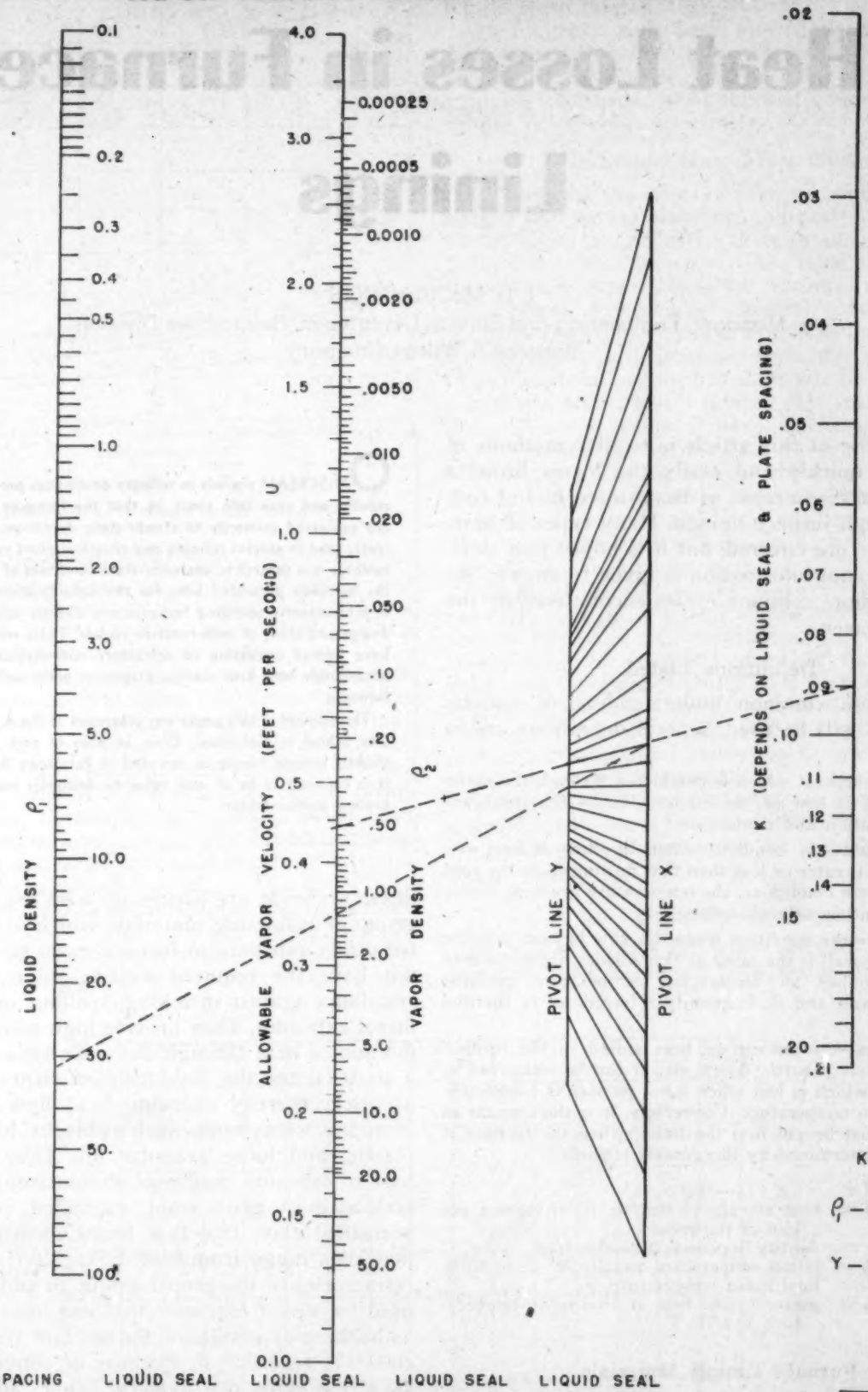
Nomenclature

k—dimensionless constant.
b—dimensionless constant.
K—a quantity which depends on plate spacing and liquid seal on the plates. Feet per second.
D—droplet diameter; feet.
U—maximum allowable vapor velocity based on empty tower total cross section; feet per second. (As derived, U is the relative velocity of vapor and droplets.)
u—viscosity of vapor; pounds (mass) per foot per second.
ρ_1—density of liquid droplet
ρ_2—density of vapor
these have the same units and are measured at the conditions of operation of the tower.
g—acceleration due to gravity; feet per (second)^2.
F—force; pounds (mass) feet per (second)^2.

REFERENCES

[1] Carey, Chem. & Met. Engr. 46 314 (1939).
[2] Keyes & Deem, Chemical Engineers' Manual, John Wiley & Sons, Inc, 1942.
[3] Stone, Petroleum Refiner, 25 124 (1946).

VAPOR VELOCITY ESTIMATION NOMOGRAPH



KEY:

$\rho_1 - \rho_2 - X$

$Y - K - U$

$$U = K\sqrt{\frac{\rho_1 - \rho_2}{\rho_2}}$$

PLATE SPACING (INCHES)	LIQUID SEAL (0.5 INCH)	LIQUID SEAL (1.0 INCH)	LIQUID SEAL (2.0 INCHES)	LIQUID SEAL (3.0 INCHES)
6	.02 – .04	———	———	———
12	09 – .11	.07 – .09	.05 – .07	———
18	.15	.14	.12	.09
24	.185	.17	.16	.15
30	.195	.185	.18	.175
36	.205	.195	.19	.185

Based on constants given by Carey, Chemical and Metallurgical Engineering, 46 314 (1939).

Heat Losses in Furnace Linings

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THE purpose of this article is to give methods of determining quickly and easily the losses brought about in furnaces because of heat stored in and conducted through furnace linings. Many types of heating cycles are not covered, but it is hoped that sufficient background information is given to answer the majority of more common cycles encountered by the furnace engineer.

Definitions Listed

To assure a common understanding of various terms which will be used, several definitions are in order.

Heat flow—the heat which is conducted through the material and which is lost on the cooler side by the combined effects of radiation and convection.

Unsteady state—the condition when the flow of heat into the hot face is greater or less than that flowing from the cold face. Under these conditions, the temperature gradient within the wall is continuously changing.

Steady state—the condition when the flow of heat into the hot face of the wall is the same as that flowing from the cold face. This implies an unchanging temperature gradient through the wall and is frequently referred to as thermal equilibrium.

Heat storage—the amount of heat stored in the furnace lining, walls, arch, hearth, doors, etc. It can be visualized as the total heat which is lost when a hot furnace is completely cooled to room temperature. Conversely, it is the amount of heat which must be put into the lining when the furnace is heated. It is determined by the general formula:

$$H = \quad \times (T_2 - T_1) \times C_p$$

in which
- H = heat storage in Btu/sq. ft. of surface per foot of thickness
- $=$ density in pounds per cubic foot
- T_1 = initial temperature, usually 70° F. or 80°F.
- T_2 = final mean temperature, F.
- C_p = mean specific heat at final mean temperature Btu/lb./F.

Furnace Lining Materials

Furnaces above 800° F. are normally lined with materials known as refractories which are capable of withstanding the furnace temperatures without melting or shrinking, which have a resistance against cracking and spalling under sudden temperature changes. These may be either dense firebrick or lightweight insulating firebrick.

Frequently the exposed refractories, particularly dense firebrick, are backed up with one or more of a group of insulating materials which are not suitable for direct exposure to furnace gases because they do not have the required melting-point properties or resistance against shrinking, spalling, or cracking for direct exposure. They provide high resistance to conduction of heat through the walls because they have 6 to 10 times the insulating efficiency of standard firebrick, thereby reducing heat flow losses. They come in various forms such as blocks, blankets, brick, plastic, and loose granular fill. They may have a base of asbestos, magnesia, diatomaseous earth, mineral, slag or glass wool, expanded vermiculite, or porosified clay. Hot face limits for such insulating materials range from 550° F. to 2500° F. Insulating refractories of the proper grade, in addition to being used for direct exposure to flame, may also be used as backing-up insulation for hot face temperatures of 2900° F. to 3000° F. Because of convenience of installation with one type of labor, and for design advantages, many furnace builders prefer the brick type of insulation.

Of the refractories which may be used directly exposed to furnace gases, we are interested in two main classifications, standard firebrick and insulating firebrick.

Standard firebrick are dense hard brick made of refractory clays. They range in weight from about

ON-STREAM periods in refinery continuous processes run into months and even into years, so that the furnaces in these units are subjected primarily to steady-state operation. Reactors currently used in several refining and chemical plant cyclic processes, however, are subject to unsteady-state conditons of operation, and the methods presented here for the consideration of heat flow in intermitently operated furnaces are directly applicable to the design and study of such reaction vessels. These reactors normally have linings consisting of refractory and insulating materials, accordingly have heat storage properties quite similar to those of furnaces.

The original of this paper was presented at the A.G.A. Industrial Gas School in Columbus, Ohio, in May of this year, and this slightly revised version is included in Petroleum Refiner because it is believed to be of real value to designers and operators of process units.—Editor.

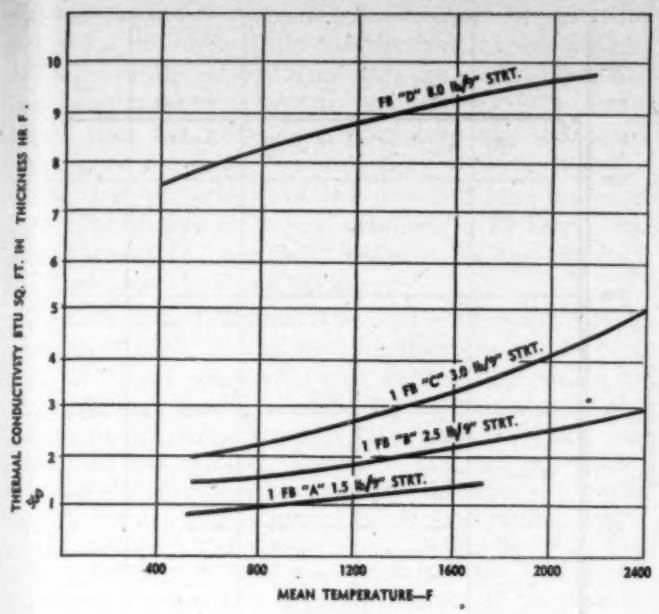
THERMAL CONDUCTIVITY BTU SQ. FT. IN THICKNESS HR. F.
FB "D" 8.0 lb/9" STRT.
1 FB "C" 3.0 lb/9" STRT.
1 FB "B" 2.5 lb/9" STRT.
1 FB "A" 1.5 lb/9" STRT.
MEAN TEMPERATURE—F

FIGURE 1

Thermal conductivities of various weight refractories

125 pounds to 140 pounds per cubic foot. This corresponds to approximately 7½ to 8 pounds per 9-inch straight. (A 9-inch straight is a brick 9 inches long by 4½ inches wide by 2½ inches thick). Their thermal conductivity is relatively high.

Insulating firebrick are made from the same type of clays as standard firebrick. However, they are processed to make them highly porous. This may be accomplished by several methods, usually by the intimate mixing with the clay of finely divided carbonaceous material which is burned out on firing, thereby leaving a multiplicity of small pores. The effect of the pores is to bring about a marked reduction in weight and to reduce the thermal conductivity with respect to standard firebrick.

There is a close, but not infallible, relationship between weights and thermal conductivities of insulating firebrick. Generally speaking, the thermal conductivity increases in direct proportion with the weight, although the effect of pore size may vary this relationship somewhat, particularly in the higher temperature ranges.

On Figure 1 have been plotted the thermal conductivities of three commercial insulating firebrick and a fireclay brick weighing 8.0 pounds/9-inch straight. The increase of thermal conductivity with weight is brought out clearly.

Increased Heat Flow Shown

To translate the effect of thermal conductivity and weight into actual heat-flow and heat-storage values for different wall constructions in the steady state, Table 1 has been prepared. This table shows the increased heat-flow losses at various temperatures which result from higher thermal conductivities of the brick shown in Figure 1, as well as increased heat-storage losses with increasing weight. Two illustrations have been included to show what happens when a standard firebrick is insulated (4½ inches D + 2½ inches A and 9 inches D + 4½ inches A). The heat flow drops sharply but the heat storage increases correspondingly. This is because the cooler side of the firebrick has been raised by many hundreds of degrees on account of the backing-up insulation. Thus, its final mean temperature is much higher, with a consequent higher storage.

Weight is also important in its effect on time required to heat up. Figure 2 shows a curve of relative heat-up rates and fuel requirements developed from observations on identical slot-type forge furnaces lined with standard firebrick and with two different weights of insulating firebrick. Trinks[1] has developed some excellent curves on relative heating times of standard firebrick and insulating firebrick which are useful for design purposes.

Because of the thermal advantages of insulating firebrick, they have become universally accepted in nearly all types of industrial furnaces over the past fifteen years.

Unsteady State

An understanding of what temperature changes occur within a refractory wall section during the un-

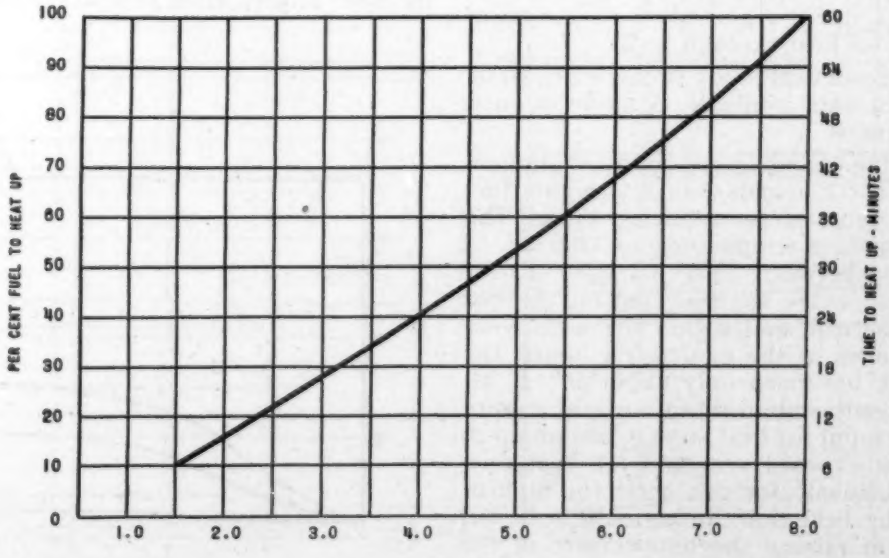

FIGURE 2

Comparison of fuel requirements and heating-up times required on empty slot-type forge furnaces lined with three different weight refractories.

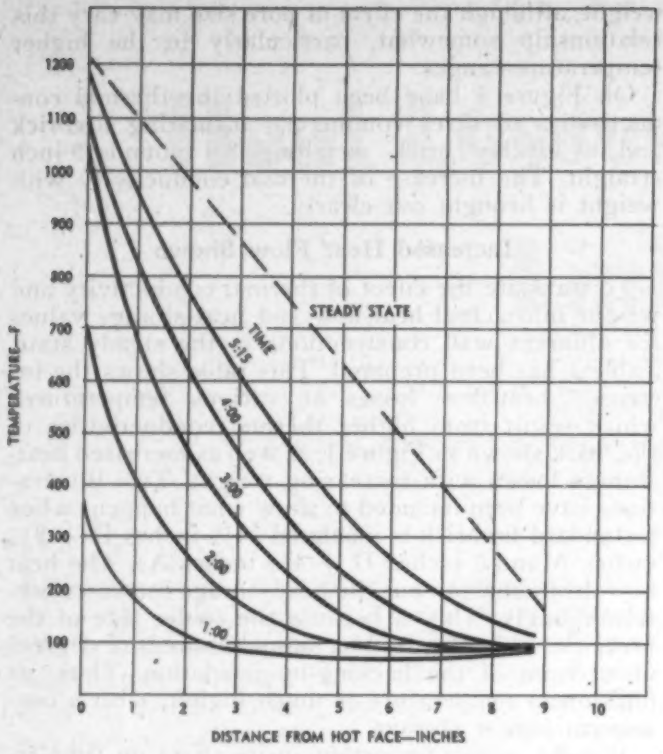

FIGURE 3

Time temperature unsteady state only. 9-inch insulating (2 lb.).

steady state is of help in applying most intelligently the mass of steady-state data which is widely published by many manufacturers and in numerous textbooks.

Within recent years, a useful tool which has become available for investigating the unsteady state from theoretical considerations is the Schmidt diagram. Trinks[1] gives a method for determining graphical solutions by the Schmidt method to single material walls, and Patton[2] gives a modification for composite walls. Schack[3] describes a simple arithmetical method of solution. For cycles involving alternate heating and cooling at various temperatures for different periods of time, the Schmidt diagram offers an excellent means of forecasting heat requirements. Also Paschkis[4] has devised a method of electrical analogy of the flow of heat through walls.

Aside from the theoretical study of unsteady state, there are actual test data available. A study of such data is of some interest.

Figure 3 shows the changing temperature gradient within a 9-inch IFB (2 pounds/9-inch straight) furnace wall on a typical stress relieving cycle. The charge was brought to a temperature of 1200° F. in 3½ hours and held between 1200° to 1250° F. for 1¾ hours. Thermocouples were located on the hot and cold face of the wall and within the wall. Note particularly how, even at the end of 5¼ hours, the casing temperature has risen only about 40° F. although the final steady-state condition would require an 80° F. rise. The input for heat storage amounted to 2390 Btu/sq. ft. of exposed area and for heat flow 146 Btu/sq. ft. Obviously for this cycle the bulk of the losses is not by heat flow through the wall but is brought about in raising the temperature of the brick: i.e., heat-storage losses.

If all of the operating runs were of such duration, the 9-inch wall thickness is questionable from a purely thermal standpoint. In this particular furnace the

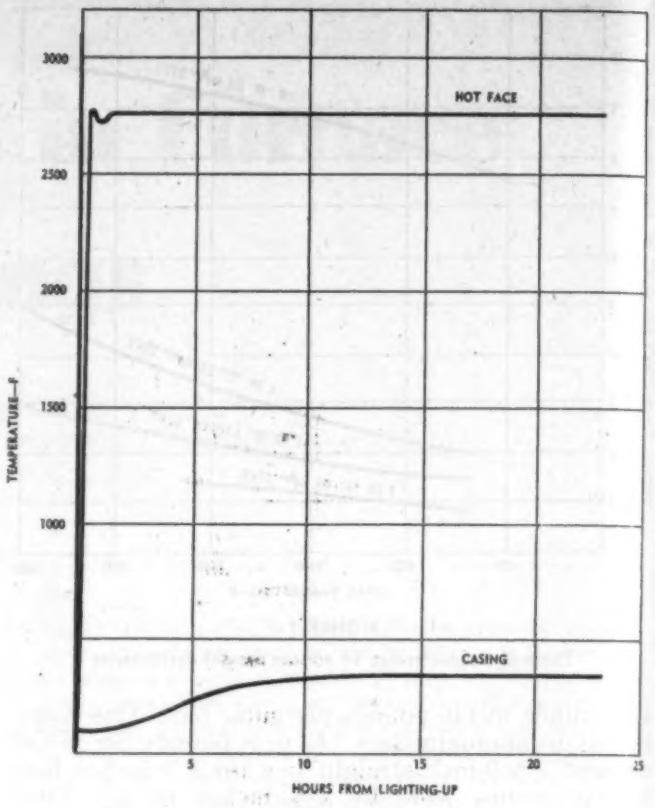

FIGURE 4

Time temperature gradient, unsteady to steady state 9-inch IFB (2 lb.).

runs varied in length, and design considerations made a 9-inch lining desirable.

Figure 4 shows hot- and cold-face temperatures of an arch of 9 inches IFB (2 pounds/9-inch straight) heated from cold to 2750° F. in less than 15 minutes (remarkable in itself) and held for 24 hours. Only the hot-face and casing temperatures were measured on this run. The actual test data indicated that the steady state was reached in 18 hours.

Figure 5 shows a wall of 9-inch IFB (2 pounds/9-inch straight) backed up with 1-inch high temperature block insulation raised in a matter of minutes to 1800° F. then after 18 hours, to 2000° F. A ½-inch

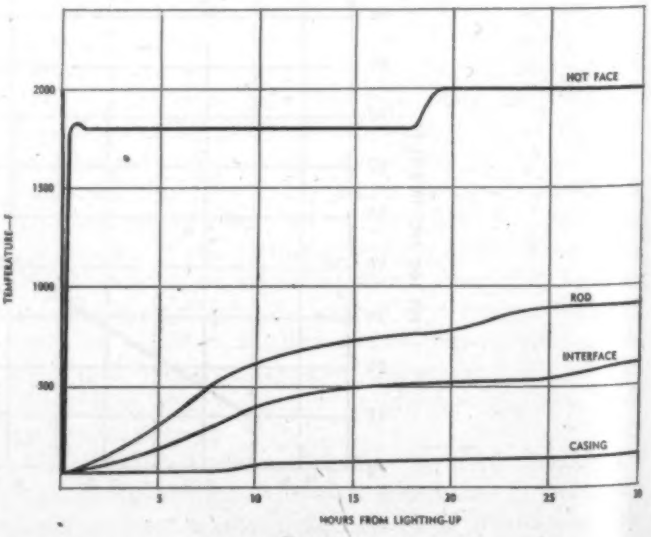

FIGURE 5

Time temperature gradient, unsteady state to steady state. 9-inch IFB (2 lb.) + 1-inch HT block insulation.

rod was buried in the wall as an anchor, its centerline being 7-9/16 inches from the hot face. It was held by eyebolts to the casing. Note that the steady state had not been quite reached at the end of 18 hours, at which time the hot-face temperature was increased. Then note the long time lag before the interface and casing felt the effects of the new hot-face temperature. The steady state was attained in 32 hours, but would probably have been reached for the 1800° F. hot face alone in about 20 hours.

Figures 6 and 7 show two different walls heated quickly to 1600° F. and held for many hours. In each case, a ½-inch anchoring rod, held to the casing by eyebolts, was buried in the wall, its centerline being 3-1/16 inches from the hot face. The interface and casing of the wall in Figure 6 (5½ inches thick) reached the steady state in about 11 hours. For the wall in Figure 7 (6½ inches thick) the interface and casing reached the steady state in about 14 hours. The rod temperatures were consistently below the gradient through the brick, presumably because of the conduction effects of the eyebolts holding the rods to the casing.

In general, it would appear that with insulating firebrick, for each inch of thickness of a wall including insulation, it takes approximately two hours to attain steady-state conditions. From a practical viewpoint, though, the steady state is essentially attained in 1½ hours per inch of thickness. These conclusions apply only to walls in which the final hot-face temperature is attained reasonably soon after the furnace is lighted.

Combustion Considerations

It is not the purpose of this discussion to illustrate the manner of determining a complete heat balance, nor to explain combustion processes. For purpose of clarity, though, a few points should be mentioned.

In making a complete heat balance, we should take into account all of the heat which goes into the furnace lining (walls, arch, hearth, doors), heat conducted through metal extending into the furnace, heat absorbed by the ware, heat radiated through openings, and heat which is lost up the stack as sensible heat in products of combustion including excess air, moisture, and incomplete combustion.

For a given exit gas temperature and fuel we are faced with a minimum sensible heat loss. Assume a natural gas fired with 10 percent excess air leaving a furnace at 1800° F. for which we find the total amount of heat going up the stack to be 52 percent. This means that only $100 - 52 = 48$ percent of all fuel burned in the furnace is available for work, whether for heating the ware, heating the lining, or flowing through the walls. Thus, if we require 48 Btu for the lining, we must introduce 100 Btu into the furnace. Therefore, after we determine the number of Btu absorbed by the walls, we must divide that quantity by the fraction of available heat to determine the required heat input to the furnace to satisfy the wall requirements.

All data presented in this discussion will be on a square-foot basis. To determine total furnace requirements, the total mean area of each portion of the furnace; i.e., walls, arch, hearth, doors, etc., should be measured, and the areas multiplied by the factors applying to the various sections with due regard to different wall thicknesses and constructions in each area.

With the background thus far covered, we are in a position to determine heat losses on furnaces operating under several different cycles.

Continuously Fired Furnace

Let us first consider a furnace which is operating 24 hours a day for seven days a week for months on end. This would be typical of some continuous oil stills.

In such a furnace, the heat flow is our principal loss, and the heat storage is of secondary importance because of the infrequency of shutdowns. Therefore, low thermal conductivity is a determining influence in the selection of a lining.

Assume that a unit operates 50 weeks out of the

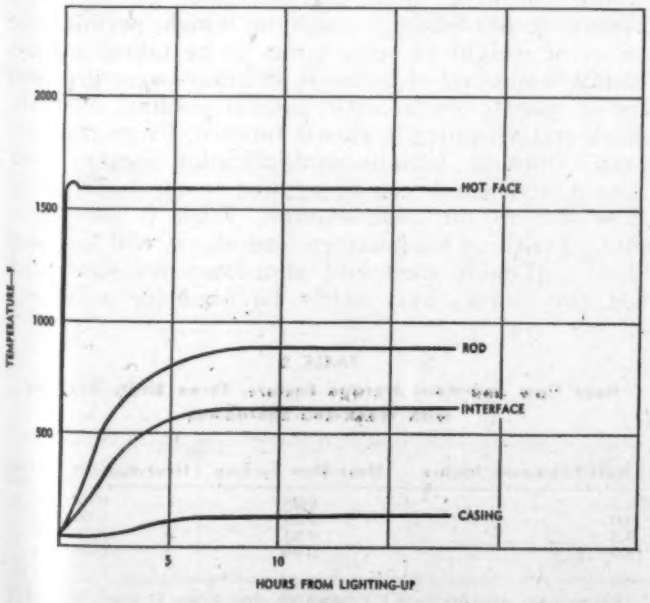

FIGURE 6
Time temperature gradient, unsteady state to steady state. 4½-inch 1FB (2 lb.) + 1-inch HT block insulation.

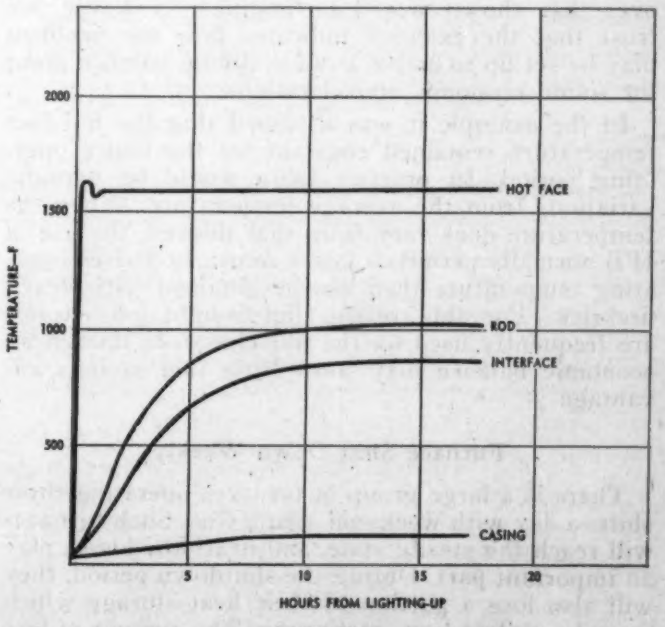

FIGURE 7
Time temperature gradient, unsteady state to steady state. 4½-inch 1FB (2 lb.) + 2-inch HT block insulation.

TABLE 1

Heat Flow and Heat Storage Capacities of Several Walls Under Steady State Conditions

THICKNESS OF WALL IN INCHES	HOT-FACE TEMP—F. 1000 HF	1000 HS	1400 HF	1400 HS	1800 HF	1800 HS	2200 HF	2200 HS	2600 HF	2600 HS
	BTU PER SQUARE FOOT OF WALL									
4½" A	160	1085	262	1645	381	2230	510	2830	....	....
4½" B	266	1680	420	2530	599	3410	806	4350	1042	5290
4½" C	356	2170	574	3270	835	4420	1146	5610	1520	6840
4½" D	1082	6980	1691	10,300	2400	13,750	3100	17,100	3875	20,600
4½" D + 2½" A	232	10,700	362	16,070	516	21,720	695	27,430	890	33,350
9" A	80	2080	135	3170	192	4280	258	5475	....	....
9" B	140	3160	220	4800	312	6480	416	8230	535	10,080
9" C	188	4090	302	6140	436	8330	596	10,580	785	12,980
9" D	620	12,790	952	19,000	1315	25,300	1694	31,850	2095	38,550
9" D + 4½" A	132	20,910	206	31,680	291	42,710	388	54,180	497	65,620

WEIGHTS—1 FB "A" = 1.5 lb./9" Strt. 1 FB "B" = 2.5 lb./9" Strt. 1 FB "C" = 3.0 lb./9" Strt. FB "D" = 8.0 lb./9" Strt.

TABLE 2

Economic Study of Annual Heat Loss by Walls from Continuously Operated Furnace at 188° F., 50 Weeks Operation Per Year, Two Shutdowns

1 CONSTRUCTION	2 Heat Flow Btu/Sq. Ft.	3 Heat Storage Btu/Sq. Ft.	4 Total Input To Wall Millions of Btu/Sq. Ft.	5 Total Input To Furnace Btu/Sq. Ft.	6 Fuel Cost per Soft at 40c per Million Btu	7 Saving in Fuel Cost of 9" FB per Sq. Ft.	8 Installed Cost per Sq. Ft.	9 Increased Installed Cost Over 9" FB per Sq. Ft.	10 Net Saving Over 9" FB at End of First Yr. per Sq. Ft.	11 Annual Savings After Full Depreciation per Sq. Ft.
9" FB	11,046,000	50,600	11.097	23.12	$9.25	.....	$2.43	.....	.....	.....
9" FB+4½" IFB "A"	2,444,400	85,420	2.530	5.27	2.11	$7.14	3.78	$1.35	$5.78	$7.14
9" IFB "A"	1,612,800	8,560	1.621	3.377	1.35	7.90	2.69	.26	7.63	7.90
9" IFB "B"	2,620,800	12,960	2.634	5.488	2.20	7.05	2.69	.26	6.78	7.05

Col. 2—Annual Heat Flow (Btu/sq. ft.-hr. ÷ 8400 hr.)= Btu/sq. ft.
8400 hr. = 50 weeks × 7 days × 24 hr.
Col. 3—Heat Storage: Storage at Steady State × 2 (No. Shutdowns per year) = Btu/sq. ft.
Col. 4—(Col. 2 + Col. 3) ÷ 1,000,000
Col. 5—Input to Wall (Col. 4) ÷ Available Heat (Assumed as 0.48)
Col. 8—FB—$ 75.00/M Delivered
10.00/M for Mortar
105.00 for Labor
IFB—$115.00/M Delivered
10.00/M for Mortar
85.00/M for Labor
12.8 Brick/sq. ft.—in 9" Wall
6.4 Brick/sq. ft.—in 4½" Wall
Col. 10—Col. 7 minus Col. 9 based on one year write-off of extra cost
Col. 11—Same as Col. 7
Fuel—Natural Gas 1,000 Btu/cu. ft. @ 40 cents/thousands cu. ft.

year with two shutdowns a year of one week each. In this case in computing the heat flow, we ignore the relatively small period of unsteady state and multiply the hourly steady-state flow by the total hours of operation. Table 2 has been prepared to summarize the results on such a furnace operating at 1800° F. It is apparent that if standard firebrick must be used, it should be well insulated. If the economics were carried out to the end point, additional insulation over that shown would be justified. However, we trust that the example indicates how the problem may be set up to arrive at an optimum balance point for sound economic considerations.

In the example it was assumed that the hot-face temperature remained constant for the entire operating period. In practice there would be periodic variations from the average temperature. When the temperature does vary from that desired, the use of IFB normally permits a faster return to desired operating temperature than can be obtained with heavy firebrick. For this reason lightweight refractories are frequently used on the hot face even though an economic balance may show little fuel savings advantage.

Furnace Shut Down Weekly

There is a large group of furnaces operating three shifts a day with week-end shutdowns. Such furnaces will reach the steady state, and heat-flow losses play an important part. During the shutdown period, they will also lose a portion of their heat storage which must be replaced on starting up. The amount of loss depends upon the type and thickness of lining and how tightly the furnace is closed. It is becoming increasingly common practice in some plants to fire the furnaces periodically over the shutdown period to prevent them from becoming too cold.

The exact determination of losses is complicated by variation in plant practices. A tightly closed furnace will lose less heat than one with dampers and doors open. Both Mawhinney[5] and Trinks[1] have offered solutions based on field results and theoretical studies.

The following method is presented as offering a means of obtaining a solution which permits the effect of weight of refractories to be taken into account. A number of Schmidt diagrams were prepared for a weekly cycle with natural cooling over the week-end assuming a closed furnace. From the data thus obtained, various multiplication factors were determined which can be applied to the hourly heat flow and to the heat storage. Table 3 lists these factors with an explanatory formula. It will be noted that a 47-hour week-end shutdown was assumed, but the factors may safely be used for a furnace

TABLE 3

Heat Flow and Heat Storage Factors, Three Shifts Per Day with Week-End Shutdowns

Wall Thickness, Inches	Heat-Flow Factors	Heat-Storage Factors
4.5	0.98	0.97
9.0	0.96	0.76
13.5	0.93	0.58
18.0	0.93	0.48

Factors are approximate for furnaces shut-down 47 hours per week, tightly closed.

Heat input to furnace per sq. ft. of wall = [(steady-state heat flow × heat-flow factor × hr. firing) + (steady-state heat storage × heat-storage factor)] ÷ fraction available heat.

which varies from this period by several hours either way.

As an example assume a wall of IFB "B" (2.5 pounds/9-inch straight) in a furnace operating steadily at 2200° F. for 121 hours a week. From Table I the heat flow is 416 Btu/sq. ft./hr. and the heat storage is 8230 Btu/sq. ft. The available heat of the gas will be assumed as 38 percent. Then the heat input to the furnace per week.

$$= \frac{416 \times 0.96 \times 121 + 8230 \times 0.76}{0.38}$$

$$= \frac{48280 + 6225}{0.38}$$

$$= 143{,}500 \text{ Btu/sq. ft.}$$

In a similar manner, 9 inches of firebrick would be found to require a weekly heat input of 581,500 Btu/sq. ft.

For composite walls of two types of insulating firebrick, the same factors can be used without serious error. For firebrick backed up with insulation, the factors should be reduced, depending on wall thickness and amount of insulation.

Intermittently Operated Furnaces

Perhaps the majority of furnaces in which we are interested are either fired only once or twice a week, or one shift a day for five days a week. This would be representative of most heat-treating, forge, and pot furnaces. Depending on the manner of operation and wall thickness, they may never reach the steady state. They have a long period to lose heat each night and consequently heat storage is of extreme importance.

For furnace operating from a cold start Table 4 has been prepared to give the total input to refractories for one 8-hour shift plus heat-up times and noon hour. This table is based on the assumption that the shutdown period between lightups is sufficient to lose all residual heat. In preparing the table, a difference in heating-up time was taken into account between standard firebrick and insulating firebrick of various weights. The tabulated values should be divided by the fraction of available heat to determine the total required heat input to the furnace for the furnace lining.

For furnaces operated five days a week, it has been found that the amount of heat input each day will vary slightly. This is because on the first day the principal loss is due to heat storage which must be replaced after the week-end shutdown. The second day there is more residual heat left in the furnace and less is required for storage but a greater percentage is required for heat flow. Depending on wall thicknesses, a condition of steady daily input is not achieved until the fourth or fifth day. Therefore Table 5 is presented, giving the average daily heat losses for various walls at different temperatures. Again a difference in heating-up time was assumed for the firebrick and insulating firebrick. Also, it is necessary to divide the tabulated values by the fraction of available heat to obtain the required total input to the furnace for the lining losses.

Both Tables 4 and 5 were prepared from Schmidt diagrams. They assume a furnace closed during shutdowns, which is not always the case in plant practice, and for this reason may give lower losses than actually result. However, they do provide a quick means of determining comparative losses of various materials and wall thicknesses. Thus they permit a quick evaluation to be made in arriving at an economic thickness of the best material for the job. The tables were based on the refractories whose thermal conductivities are shown in Figure 1. A variation from those conductivities will have a slight effect on the fuel consumption, but, as the table shows, the principal consideration is weight and heat storage.

Conclusion

The study of losses in furnace linings is still in the stage of an art rather than a science. During the past fifteen years, substantial strides have been made in reducing guess work and in providing useful tools for the furnace engineer to work with. However, it cannot be overemphasized that good judgment and experience in the use of these tools are essential to obtaining the best results.

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[2] "Graphical Methods for Temperature Distribution with Unsteady Heat Flow"—Industrial and Engineering Chemistry Vol. 36, p. 990, Nov., 1944.—Temple C. Patton.
[3] "Industrial Heat Transfer," 1933.—A Schack, H. Goldschmidt, E. P. Partridge.
[4] "Heating Up of Electric Resistor Furnaces," Industrial Heating, February and March, 1946.—Dr. Victor Paschkis.
[5] "Practical Industrial Furnace Design," 1928.—M. H. Mawhinney. "The Heating of Steel," 1945.—M. H. Mawhinney.

TABLE 4

Heat Input Btu/sq. ft. for Various Refractories Cold Start, One Shift Operation Including heating-Up Time and Noon Hours

	4½" WALL			9" WALL			13½" WALL		
Operating Temp.—F	1600	2000	2300	1600	2000	2300	1600	2000	2300
FB—8.0 Lb.	30,800	40,900	48,800	27,700	36,000	42,500	27,000	34,900	41,200
IFB—3.0 Lb.	9,400	12,900	15,800	8,600	11,400	13,600	8,600	11,300	13,400
IFB—2.5 Lb.	7,000	9,500	11,500	6,600	8,700	10,400	7,000	9,200	11,000
IFB—1.5 Lb.	4,500	6,100	7,300	4,000	5,700	6,800	4,200	5,500	6,600

TABLE 5

Heat Input Btu/sq. ft. for Various refractories average of Five-Day Week for One Shift Operation Including Heating-Up Time and Noon Hour

	4½" WALL			9" WALL			13½" WALL		
Operating Temp.—F	1600	2000	2300	1600	2000	2300	1600	2000	2300
FB—8.0 Lb.	28,700	38,200	45,700	20,700	27,000	32,100	16,400	21,400	25,300
IFB—3.0 Lb.	8,800	12,100	14,900	6,200	8,400	10,200	5,000	6,700	8,000
IFB—2.5 Lb.	6,500	8,800	10,700	4,700	6,300	7,500	3,900	5,200	6,300
FB—1.5 Lb.	4,100	5,700	6,900	2,900	4,100	4,900	2,400	3,200	3,800

The Importance of Flexible Pipe Supports

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(Presented at 12th Midyear Meeting, API Division of Refining held in June at St. Louis.)

IT HAS been recognized by the engineering profession that total pipe stress is the addition of bending, torsional shear, longitudinal and circumferential pressure stresses. Yet, unless careful study is given to the design and selection of spring supports which will maintain a balanced pipe suspension system, the transfer of weight from one hanger to another will be the cause of an additional type of stress that warrants consideration insofar as the safety factor of the entire system is concerned. This paper will refer to this as weight transfer stress and will show its relative value compared to total pipe stress.

When a pipe suspension system is properly designed:

(I) The sum of the pipe weights must equal the sum of the supporting forces;
also
the sum of the moments of piping weights acting at their centers of gravity and the supporting forces shall be equal to zero.

While it takes careful detailing and complicated calculations to satisfy these requisites, they are necessary in the selection of flexible supports.

The trend towards higher and higher temperatures has produced developments in flanged joints, valve design, expansion bends to provide a more flexible system, welding procedure and also metallurgy that make possible the operation of power and processing plants and refineries at temperatures up to 1100° F. or more. The real need for development in all of these fields was brought about by actual failure of some system or the calculation of certain stresses that would ultimately lead to failure.

The design of pipe hangers is often looked upon as simply a matter of adequate strength to hold the pipe in a fixed position. This is satisfactory for piping that operates at a constant or near room temperature. Since it is customary to assume that piping materials are at or near the same temperature as that of fluid or vapor contained in the system, we are faced with the problem of thermal expansion. Using the coefficient of expansion for 1000° F., 1000 linear feet of pipe would expand 9.4 inches.

When this thermal expansion takes place, the resultant forces induced into the piping system are tremendous. The practice of using helical coil springs to allow this thermal movement to take place is quite general, but the care that goes into the design or selection of flexible supports is looked upon by many as a casual matter. In fact, many specifications covering the support of important high temperature piping will simply say, "spring hangers shall be provided." Merely to contend that this is a dangerous practice is not enough. A specific problem on the subject will let us see for ourselves the magnitude of this matter.

Let us assume that 90 feet of A.P.I. 5L, Size 10-inch, Schedule 100 pipe is fastened between two fixed terminals and extending in three planes as shown in Figure 1. So as to simplify the problem, let us further assume that there is no movement of the terminals, and no cold pull in the pipe to reduce the stress factor, and also that hangers are selected to balance completely with the weight of the piping system as outlined in requirement (I). When this system is heated to a service pressure of 775 psig and a temperature of 900° F., stress calculations show that the maximum point of stress is located at point A and that at terminal B the bending and torsional shear stress is only about two hundred pounds less. By properly combining with longitudinal and circumferential pressure stresses we conclude that the maximum combined stress is 8093 psi.*

According to allowable "S" values taken from table 22 for "Pipe in Oil Pipe System Within Refinery Limits" as shown in ASA-B31.1—1942, A.P.I. 5L would have 18,000 "S" at 100° F. and 7000 "S" at 900° F. Section 6 of Fabrication Details, Paragraph 620—Sub-paragraph G will allow a combined stress of 18,750 "S," however, Sub-paragraph H states that for temperature changes of a definite cyclic nature or for vibration they will only allow one half of Sub-paragraph G or 9375 "S." A maximum combined stress of 8093 psi, as shown in Figure 1 is well within the allowable limits.

As qualified in a preceding paragraph, these stress values assume that the piping system is fully supported. The determination of supporting forces is concluded in Figure 2, and while no effort will be made to explain these calculations, the method employs a mechanical beam principle as prepared by E. Howarth published in Power Magazine, July, 1947. A method for calculating weight balance is also available in literature published by the Grinnell Company, Inc.

With change in axial configuration of the piping

* Determining maximum combined stress in this paper employed the S. W. Spielvogel method.

system during the cycle of deflecting from cold to the hot position, it will be noted that the vertical shift at hanger H-3 is 2-5/16 inches up from cold to hot. In the event that the hangers provided for this example are of the Constant Support type, they will continue to support the entire weigh of he piping and will have no effect on the total stress. In this type of hanger the spring forces are transmitted through a bellcrank lever that compensates for the variation in helical coil springs. Sometimes it is economical to make use of the constant support type of hanger in order to hold within stress limits and avoid adding more pipe for flexibility as well as conserving the enginering time required to re-design the system.

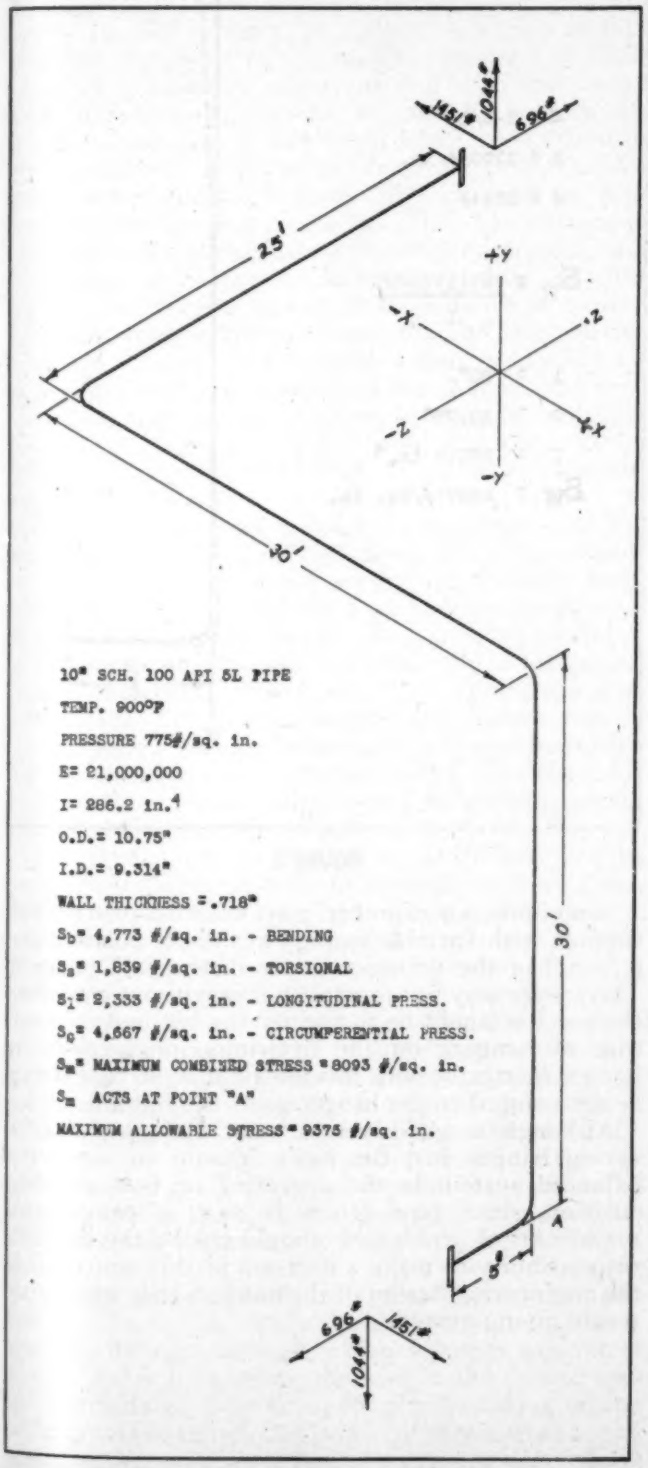


FIGURE 1

However, when the usual type of helical coil springs are used for the supporting system, thermal reflection will cause a variation in the supporting forces. It is an inherent characteristic of helical coil springs, that their forces vary in direct proportion to the deflection of the springs. It is always desirable to design a spring that will produce the least possible variation. Since the gravitational forces remain the same in either the upper or lower position of the system, any variation in the opposite reaction of the hangers will bring about a transfer of weight from one hanger to another.

A study of Figure 3, which is a section of the stress illustration, drawn in a single plane, will show the relative position of the piping in the hot and cold position.

(II)

W = Amount of weight transfer due to thermal expansion of the riser

$W = \Delta K$

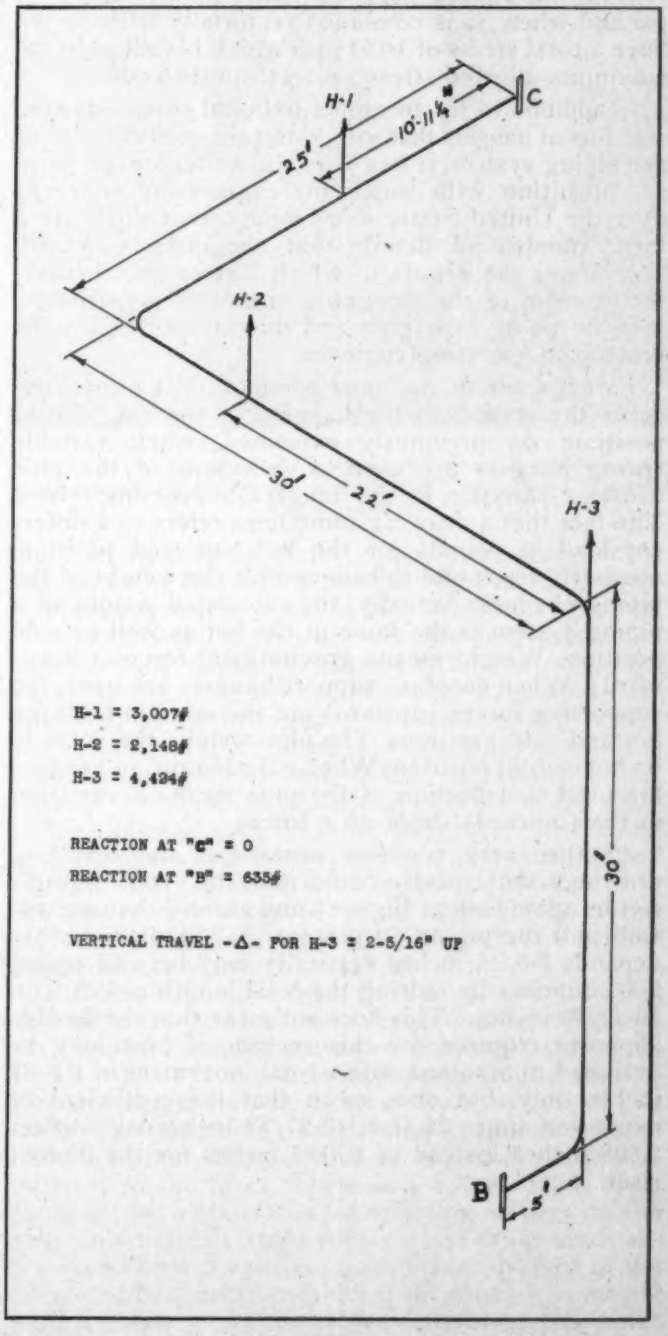


FIGURE 2

Δ = Amount of deflection in inches
K = Spring constant in #/inch.

It is generally considered to be a good spring hanger if the variability factor does not exceed 25 percent of the load per inch of deflection. Such a spring used in Figure 3 would let W be equal to 2544 pounds.

In order to transpose this weight into terms of stress for addition into the total combined stress previously calculated in Figure 1, the author is suggesting the following simple equation, considering the horizontal section of pipe acting as a cantilever beam. (III)

S_w = Stress at fixed end due to weight transfer

$$S_w = \frac{(W)\,(l)\,(D/2)}{I} \quad \text{or} \quad \frac{(\Delta K)\,(l)\,(D/2)}{I}$$

l = Length of pipe from hanger location to fixed end in inches
D = Outside diameter of pipe in inches
I = Moment of inertia of pipe.

With this equation we find that S_w is equal to 2867 psi and when S_w is combined vectorially with S_m we have a total stress of 10,548 psi which is well over the maximum allowed stress set forth in the code.

In addition to the foregoing technical reasons for the selection of hangers that will protect the safety factors of the piping system, it has been the writer's experience in consulting with important engineering concerns over the United States and Canada, that there are a large number of details that are often confused. Sometimes the details to which I refer may be perfectly clear to the designing engineer, nevertheless may be poorly specified and misinterpreted by the erector or operating engineer.

Perhaps one of the most common difficulties concerns the setting of the hangers in the hot or cold position. As previously explained, when variable spring hangers are used, a deflection of the pipe causes a variation in the hangers' supporting forces. The fact that a drawing sometimes refers to a different load in pounds for the hot and cold position, obviously leads one to believe that the weight of the piping changes. Actually, the calculated weight of a piping system is the same in the hot as well as cold position. Weight means gravitational forces (downward). When constant support hangers are used, the supporting forces (upward) are the same in both the hot and cold positions. The pipe weighs the same in its hot or cold position. When variable spring hangers are used, a deflection of the pipe means a variation in the (upward) supporting forces.

Another very common mistake is the result of drawings that specify "cold pull" or "cold spring." Let us again look at Figure 3 and assume that we will cold pull the piping 50 percent. A 30-foot riser that expands 2-5/16 inches vertically may be cold pulled 1-5/32 inches by cutting the total length as "29 feet, 10-27/32 inches." This does not mean that the flexible supports required for this section of pipe may be designed to accommodate a total movement of 1-5/32 inches only, but does mean that the coefficient of expansion times 29 feet, 10-27/32 inches will deflect 2.308 inches instead of 2.3125 inches for the 30-foot riser.

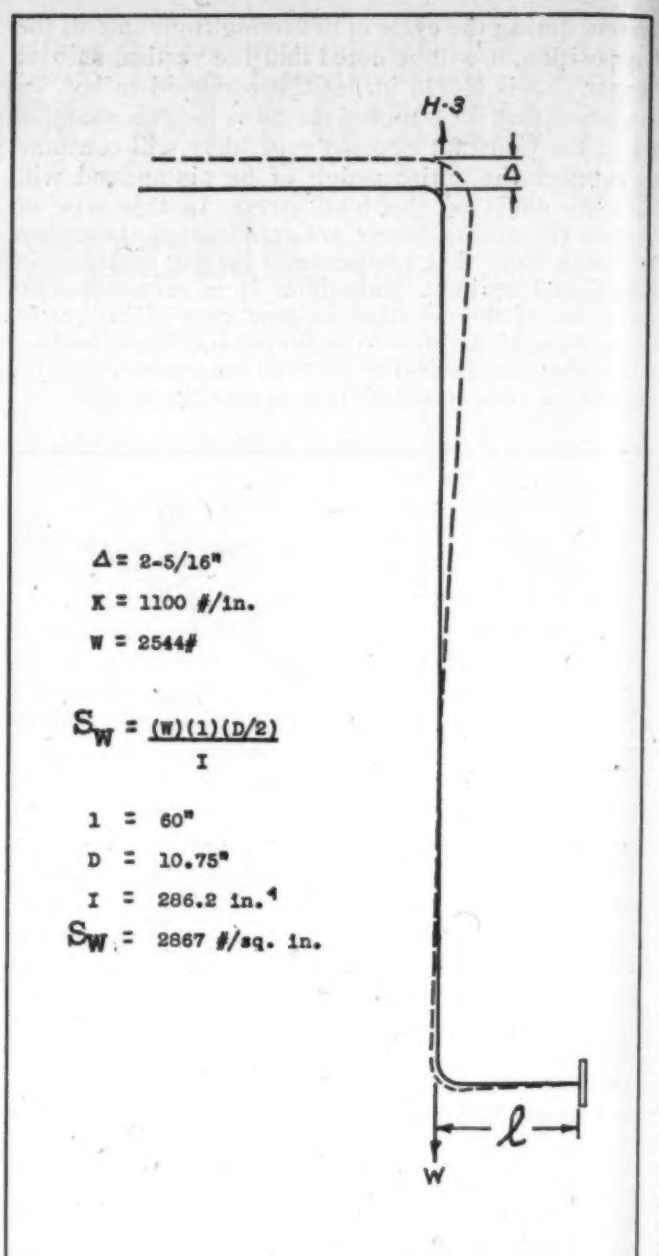


FIGURE 3

Sometimes an engineer may want to provide full support with variable springs in the hot position and have all of the variation occur in the cold position. The proper way to accomplish this without confusing the erector would be to specify the hot and cold setting of hangers on the drawings, or furnish the hanger fabricator with this information so that it may be die-stamped on the hanger prior to shipment.

Although a good erector can always deflect a spring hanger just the right amount to produce a balanced system in the operating or non-operating position, since pipe stress is such a complicated mathematical problem, it should not be the erector's responsibility to make a decision in this matter. It is the engineering design of the hangers that will assure a safe piping system.

Union Oil Company Produces High-Melting Paraffin Waxes From Lubricating Oil Cuts

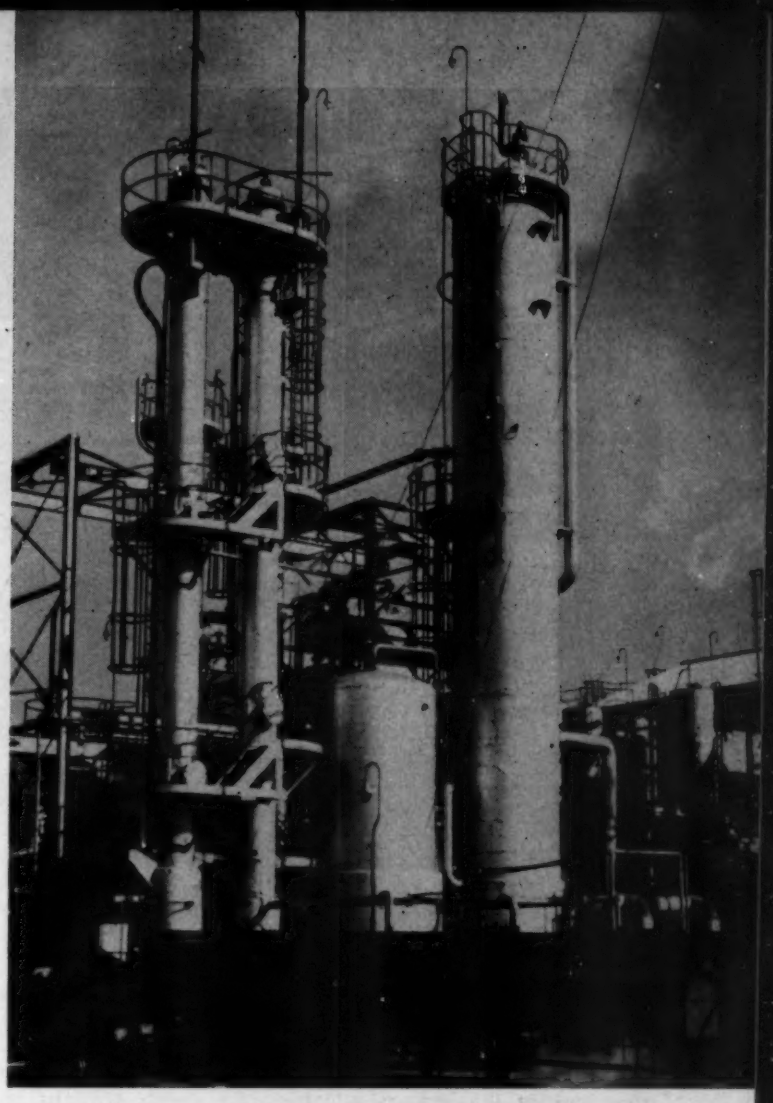
JOHN C. ALBRIGHT

PRODUCTION of high-melting-point paraffin waxes in the refinery at Oleum involves certain methods developed by Union Oil Company of California as a result of experimenting with the waxes from lubricating oil stocks. It was observed that a straight-chain wax is free of oil when crystallized in the oil. Inspection of waxes disclosed that wax obtained from oil by propane chilling could be prevented from forming into solid cakes by continuous agitation and stirring during the chilling process, and that a pumpable slurry could be obtained by the addition of certain types of oils or solvents under closely controlled temperatures. Inspection of the slurries produced in this manner showed that practically all of the high-melting waxes had crystallized and separated, oil-free, at temperatures between 50 and 100° F. Further investigations indicated that the crystals could be recovered, free of oil, in a process of washing with a solvent.

Two types of high-melting point waxes—145-150 and 160-165 AMP—and certain variants, are manufactured at Oleum. These waxes are obtained from lubricating oil cuts recovered by vacuum distillation of selected California crudes, such as that produced at Santa Fe Springs, which lends itself to the manufacture of a paraffin-base motor oil having low carbon residue. The process involved in manufacture of the company's motor oils includes propane deasphalting and dewaxing at —50 to —60° F. Certain SAE grades contain the required types of paraffin waxes and are segregated for finishing.

The crude wax is stored in 5,000-barrel tanks equipped with steam coils to maintain the wax in a fluid state so that it may be pumped to the chillers, which are scraper type pipe, jacketed, and operate in series. Each unit is fitted with pipe connections to introduce water into the jacket countercurrent to the movement of wax. To obtain crystallization, the temperature is slowly lowered to provide adequate time for crystal formation. Water under regulated temperature of 85° F. is passed through the first section of the chiller unit to reduce the temperaure of the wax from its storage temperature of 150 to 165° F. to 115 to 120° F. The flow of the wax being chilled is from the outlet of the first chiller section to the inlet of the second, where continued graduated chilling is obtained.

The second section of the chiller is similar to the first section, but in addition to the water connections, contains fittings through which solvents are introduced. Water for cooling the wax in the second section is regulated from 40 to 60° F., depending on the melting point desired, and flows countercurrent to the wax in process. Introduction of solvent is determined by the type of wax which is to be finished from the



Columns in the wax plant where solvent is removed by distillation for continuous reuse in processing wax at Union Oil Company of California's Oleum refinery.

material in process. Solvent may be introduced at any point in the second section required, at process temperatures around 100 to 105° F. Initial introduction of solvent is regulated so the individual wax crystals will retain their identity and not become caked, while subsequent additions are to create a fluid slurry so as not to increase the pressure drop above the capacity of the system, and also that the material may be pumped to subsequent operations in the process. The method of adding solvents to the mass in the chiller is such that the temperature of the solvent is approximately that of the wax at the point of introduction. If the solvent temperature were too low the wax stream would be quenched suddenly, affecting the crystal quality, and if too high there would be a tendency to soften the crystals.

The wax is pumped from the chillers to a filtering-deoiling unit, operated in two sections in series, and each section containing a solvent-mixing surge tank. Fresh solvent is added to the slurry at the inlet of the first surge tank in volume equal to half of the crude wax in process, maintaining a smooth, plastic-like condition. The mixture of wax and solvent is pumped to the filter, which is a rotary drum type, equipped with apparatus for spraying solvent on the cake as it passes certain points while the drum is revolving. The wax cake is scraped from the face of the drum and falls into a receiver from which it is moved with a screw conveyor to the outlet. At this point fresh solvent is added to the material so that it again

Wax slabbing machine, Oleum refinery of Union Oil Company of California

is slurried for pumping to the surge tank of the second filter unit. The quantity of solvent ranges from half to equal amounts of the wax, depending upon conditions and the type of wax being manufactured. The operation of the second filter is similar to the first, again washing the cake with fresh solvent to complete the process of deoiling. Deoiled wax passes through the screw conveyor to a deoiled-wax-slurry surge tank with the texture maintained with solvent.

Stripping the solvent from the deoiled wax is accomplished in a continuous process including a direct-fired tubular heater and vertical stripping column. The heated mixture passes through the furnace transfer line to a flash drum in the top of the stripping column, where the bulk of the solvent is released as vapor. Molten wax flows downward from the flash drum over stripping trays, meeting process steam introduced at the base to complete the extraction of solvent. Hot wax with a temperature of around 450° F. is removed continuously from the base of the stripping column through process lines to decolorizing section where special clays are added in an amount between 10 and 20 weight-percent of the wax. The clay is held in suspension by high-speed stirring while in the mixing tanks, and the mass of clay and molten wax flows from the decolorizing tanks to a filtration unit. A surge tank is provided in the transfer line, also equipped with a mechanical stirring device so that the slurry of wax and clay will flow uniformly to the filter. From the filter, the wax, still in the molten state, enters a vertical column where steam is employed to deodorize it. Spent clay is dumped from the clay receiver of the filter, while the wax flows to a molten-wax receiver, completely refined and on specifications ready for shipment.

From the molten-wax-storage tank, the refined material is piped to the finishing house where it is either placed in barrels, or led to one of three slabbing machines. An overhead distribution system provides means of filling the slabbing machines which receive the hot material and cool it in approximatly one hour. The slabs of wax are 19 x 12 x 1.5 inches and weigh approximately 10 pounds each. Traveling platforms are employed to supply cartons for filling with slabs.

Recovery of solvent employed to refine the high-melting-point waxes involves several steps. All finishing columns for fractionating the solvent from water and low-melting waxes and oils are interconnected in such manner that various streams are combined or separated as found expedient. The solvent and filtrate removed from the primary and secondary high-melting wax filters are combined and fed to a direct-fired tubular heater which heats the feed to a column 7 x 50 feet for the extraction of solvent from the dissolved low-melting waxes and oils. The solvent overhead here is condensed and received in an accumulator to supply reflux for tower-top control, remaining refined solvent being pumped to storage for reuse in the wax processes. Hot bottoms are pumped to another column, for additional removal of entrained solvent from waxy oils, and the waxy bottoms of this column are pumped to storage as refinery fuel.

The recovered solvent overhead from this column is condensed, combined with a portion of the condensed overhead from the refined wax solvent stripper, and pumped to a second 2 x 40-foot column for stripping of moisture. Condensed overhead from the latter column is fed to a salt drier, and from this apparatus to a separator where bottoms are discharged to waste. Overhead, after condensation, is pumped to a final column in which this solvent is combined with a portion of the solvent removed from the finished refined wax and, after finishing, returned to the reflux accumulator at the fractionator, and from this point flows to storage for reuse. Control is maintained over this process so that refined solvent will be in condition to properly extract the oil and low-melting waxes from the high-melting product.

Test Data of Union Oil Company's High-Melting Wax

Crude Wax Tests:		
Wax Grade, based on AST melting point	143-150	160-165
Oil content, percent-weight	60.0	70.4
Melting point	124° F.	133° F.
Deoiled Wax Specifications:		
Yield, percent-weight	25.6	16.2
Melting point (ASTM) range	143-150	160-165
typical	146	163
Specific gravity, typical	.922	.933
Vis. Saybolt Universal, sec at 210° F., typical	44	50
Penetration at 77° F., (needle) typical	13	12
Oil content by weight, per cent maximum	1.5	2.0
typical	0.5	0.7
Tensile strength (Perkins), psi, typical	200	240

Industrial Engineering in Refinery Maintenance

WILLIAM H. REYNOLDS
Maintenance Department, Sinclair Refining Company
East Chicago, Ind., Plant

DURING its years of amazing growth, the petroleum refining industry has outstripped other major industries in speed of development and ability to change and meet new challenges of the industrial world. This energy and creativeness has been made possible by the modern thinking and action of the industry's managers and engineers. The continual search for improved products and methods of processing has kept the industry alive and virile, always ready to meet the changes in consumer demands and often forcing these changes which mean improved and better living for all.

Because of tremendous efforts put forth in advancing the science of processing, there has been, until recently, a marked tendency to overlook the possible improvement of mechanical methods and procedures, considering maintenance only as a necessary and unfortunate cost to be charged against the finished product. This situation has been caused in part by the fact that process changes and improved techniques have always resulted in the most spectacular economies to be realized in the refinery. In other words, "why fool with dollars when hundreds can be saved?" This attitude goes back to the days when a gusher was the only kind of well worth working, but today conservation is the key word with pumping and repressuring of the wells as standard practice.

A look at the breakdown of capital expenditures in an average refinery will disclose the trend of events to date. It will be found that capital has been invested in the amounts of $20,000 to $30,000 for each member of the operating departments for the facilities required to process the refinery products. It is considered quite normal if expenditures of $400 to $600 have been made per maintenance man for tools and facilities. This comparison is not intended to indicate that these two figures should be equal or even approach, but compared with a fairly standard investment of $2000 to $2500 for maintenance facilities in other well-regulated industries, it does indicate a less attention to this important part of the refining industry.

The older manufacturing industries having developed more slowly and evenly, entered upon a campaign of mechanical improvement during and after the preliminary splurge of newness and novelty. This program of increasing efficiency is covered by the general term "industrial engineering," and is given impetus and urgency by the healthy competitive condition in most manufacturing industries. The petroleum industry is presently or soon entering a high production period, which is quite likely to develop a highly competitive market. This means that not only must the refiners improve products and marketing procedures, but they must also closely watch operating expenses in order to remain competitive. With the completion of new facility construction under way in many plants, it is believed that manufacturing costs will be essentially stabilized from the standpoint of processing the raw product, the operating costs of transforming crude oil into saleable goods. This, of course, does not mean that there will be no improvements in processing techniques, but quite probably in comparison with the developments during the war period, the changes will be of a minor nature and not appreciably change the over-all cost picture extensively.

Worthy Plant Goal

There remains the wide open opportunity of reducing that portion of the cost of products changeable to maintenance. The effect would be an increase in the maintenance work accomplished per dollar cost, or a reduction in the cost of equivalent maintenance, the former effect for the benefit of those plants fiding it difficult or impossible to handle all desirable maintenance, and the latter for those few plants already maintaining their facilities in top-notch condition at all times. This increased efficiency can be realized by the instigation of certain basic industrial engineering principles designed to provide cooperation, work planning, craft scheduling, standardization, improved procedures and a clear and understandable organization with adequate supervision. Here in a few words is outlined a sizeable task and a worthy goal for any plant. This is essentially industrial engineering as applied to the refinery, but without the usual stopwatch and motion-study procedures employed by the production-line type of manufacturing industries. In a sense, time and motion study is employed, but in

terms of hours and half-mile walks rather than microseconds and micromotions or therbligs.

It is impossible to apply in the refinery the detailed devices of industrial engineering that have evolved from study and trial and error in other major industries. This has been discovered to the dismay of a number of refiners, accounting in part for unpopularity in the oil industry of efficiency men and industrial engineers. There were unfortunately a number of inexperienced men who set themselves up as "experts" at the time when industry became efficiency-minded. These men, however, have in general left the industrial engineering business to the more reputable concerns and individuals who are attempting to bring this science to the position in the oil industry which it has enjoyed in other industries. The broad basic principles of industrial engineering are just as applicable to the petroleum refining industry as they are to the automotive industry. It is merely the tools by which those principles are applied that are as widely divergent as the equipment required to produce the finished products of these two industries.

What are the basic principles of industrial engineering as worked out and crystallized by the country's leading industrial engineers? They do not all entirely agree in detail, of course, but the basic principles would be outlined somewhat as follows: (1) Organization; (2) Cooperation; (3) Planning; (4) Standardization; and (5) Review and improvement. These are broad in scope and if properly applied to the refining industry will prove to be as valuable in increasing efficiency as found in other manufacturing industries.

The question may arise as to how employes will receive a program designed to increase efficiency. In plants where industrial engineering programs have been instigated and properly presented to employes, the success has been gratifying. It is of prime importance to outline completely the purposes and objectives of the program as well as the methods by which it will be carried out. It must be stressed that efficiency will be brought about not by working harder, but by providing better equipment, improved methods and more efficient materials, which actually will make the work easier. Back-breaking labor is not efficient nor do employes object to its elimination.

Organization

In a few companies, refining management has recently given extensive attention and study to the organization phase of improvement. This, of course, is the logical approach and beginning of efficiency, because, without organization of the proper design, there can be no economy. The history of plant organization has passed through a number of stages; however, modern management is essentially in agreement on the "line and staff" organization or slight variations. This allows the line organization to carry out its primary function of supervising, and the staff groups to attend to the assigned details, each unhampered by the press of the other problems. Most refinery operating departments, of necessity, have attained a high degree of success with this type of organization. The line supervisors operate in close cooperation with their staff groups to produce the quantity and quality of products required by the sales organization. The staff groups are many and varied, but when carefully studied, closely resemble the staff groups of other production-type manufacturers. These groups are generally referred to as the budget, yield, laboratory, technical service, research, development and others.

Maintenance Usually Separated

There is one major difference between the refining and other types of industries, however, and that is the refinery maintenance group is usually separated from the operating group and their staff organizations. Except in a few rare cases, the refinery maintenance department is entirely on its own, depending upon close cooperation, which is not always on hand. Where there is a lack of cooperation there quite likely will be difficulties on turn-around scheduling, sudden operating department plan changes, controversies over work priority, absence of a free flow of information and general confusion as to procedure. An attempt has been made by some refiners to provide staff functional groups as a part of a separate engineering department, but all too frequently these two groups are at odds and show a complete lack of cooperation. Could this be a result of improper or lack of organization? Has management been willing to provide the necessary supervisory personnel and technically trained assistants to aid the maintenance group in improvement of methods and procedures? In other words, where is the maintenance staff organization?

It is not necessary to make sweeping changes in most organizations to meet current conditions and it is highly inadvisable to do so. It is necessary, however, to maintain the organization in adequate form to handle all functions of the particular plant and be readily adaptable to changes as they arise. In most instances this can be accomplished around the existing form of the organization without seriously disrupting the group and in a surprisingly short time. The economics to be realized from functional organization alone would be quite appreciable. How much could personnel problems be reduced and general maintenance work improved if the maintenance superintendent and foremen were freed of the details of planning, scheduling, budgeting and, in general, the things with which the operating supervisors do not have to contend? How much better could all the supervisory personnel carry out their functions if they were positive of the scope of their duties, responsibilities and authority? And yet how many companies clearly outline the details of departmental activities and procedure manuals for carrying out these activities or how many provide even a simple organization chart? Without these devices, is it possible to know that there are no gaps or overlaps in the organiaztion? Is it possible to tell the inadequacies or determine the location of shortcomings of the particular organization?

The organization of the plant or department is by no means the limit or goal to be reached. It is merely the means by which cooperation may be attained for putting into practice the other principles of industrial engineering.

Cooperation

In order to achieve success in any undertaking involving more than one person it is necessary to have cooperation. One of the things which helps in gaining cooperation with a group is a concise and clear-cut statement of objectives. In other words, what are the goals toward which the men must work in coopera-

tion in order to bring credit to the group as well as to each individually? Once an organization has been established and the supervisors understand their objectives, the scope of their activities and authority, and from whom they are to receive aid and assistance on special or routine functions, then there is bound to be a tendency of all to cooperate in attaining the common objectives of the entire group.

By far the greatest factor in gaining cooperation, however, is the personal character and ability of the supervisors to create in others the desire to cooperate. The use of this factor is dependent upon management placing the men having this skill and character in key positions affecting the work of others. This emphasizes the statement that the particular organization must be built around the personnel in order to utilize fully the available talent. The cold setting-up of a perfect organization chart, then attempting to fill the little square blocks with round men has caused regret in a number of plants where in others the same organization may work beautifully. One thing must be provided for, however, and that sufficient time allowed for the supervisors to determine and eliminate the causes for any lack of cooperation.

Planning

The term "planning" covers a very broad section of the activities of industrial engineering in all industry. The production of goods must be planned to meet present and anticipated market demands. The company's financial structure must be planned for expanding facilities, close competition and other variable factors affecting the soundness of the organization. The marketing and sales departments must plan for changing and shifting product demands. Transportation departments must plan the most economical handling of products in light of the possible future position of the company with respect to sources of raw materials and sales outlets. Likewise it behooves the refinery maintenance departments to follow the lead in this respect and take advantage of the economies to be offered by careful, judicious planning of their operations.

First, it is necessary to foresee fairly accurately the amount of required and desirable maintenance work to be done over a specified period of time. The accuracy of this forecast of course is dependent upon the period of time covered. Generally, management wants a budget covering the predicted expenditures for the approaching year, and provide for a revision at the half-way mark. This is a difficult task in connection with maintenance work; however, how often has it occurred that the submitted budget indicates an expenditure far in excess of the total possible with the labor force provided. Too frequently these so-called "budgets" are merely wishing sheets, which present erroneous figures to management and the investors. If, however, the work is actually desired, then it is necessary to make provisions for the required working force and plan the work in a more realistic manner. The planning of shutdowns, and turnarounds must not only take into consideration the production capacity, but also the maintenance labor and material situation. Has the operating department ever shut down a unit, then suddenly informed the maintenance department they must have the unit back in three days, only to find that materials have not arrived or fabricated spools not completed? Also has it ever occurred that a planned turn-around is suddenly moved back a week without sufficient warning to the maintenance department? Are jobs started and stopped frequently because of other work becoming more urgent? Is there an unusual amount of lost time waiting for inspectors, or one craft waiting on another to make ready for the work? If these difficulties have been encountered it shows a very definite deficiency in the planning program of the refinery, which is quite likely to be caused by a faulty organization or lack of cooperation. Of course there are bound to be instances of changes in even the best laid plans; however, due consideration must be made for all concerned. There will be emergency shutdowns and unforeseen work, but even this can be kept to a minimum with a carefully planned inspection program.

A tool which will provide exceptional help in the hands of the maintenance supervisor is the knowledge of what work his force can undertake reasonably. Most plants do not maintain a force sufficient to handle the extreme peaks of maintenance work because it is necessary to have some back-log to smooth out the extreme valleys. To preserve this equilibrium most maintenance departments also handle a certain portion of the construction program. Without a complete knowledge of the capacities and commitments of his department, the maintenance supervisor cannot give management a clear picture of the amount of construction work that can be handled by the plant forces. Would it not be very helpful to have information at hand in a quick reference form showing the man hours available for construction or other desirable maintenance? This could be long or short range predicting with revisions as frequently as deemed advisable.

Schedule of Day-to-Day Work

More specifically a planning and scheduling program of the day-to-day work will show the most immediate and tangible results. Although some refiners have worked out very simple and workable scheduling systems, there are a great many who still depend upon the early morning decisions of the maintenance supervisor or craft foreman regarding where the men are going to work that day. As one master mechanic put it, "I know where all the men will be at 8 o'clock, but no one knows where they will be at 9 o'clock." Here obviously was a lack of planning, scheduling, and cooperation with the operating departments. His particular difficulty was the operators' requests all through the day for handling "emergency" jobs, which, upon analysis, proved to be 90 percent procrastinated rather than emergency jobs. There will, of course, always be some unforeseen and genuine emergency work, but at least one well organized refinery has reduced this to a comparatively non-existant point.

There are fairly obvious basic principles in developing a sound planning system for the day's work. First, there should be a simple job order system—a means of requesting work to be done. Second, there should be a review of the job by someone capable of determining men and materials required. Third, there should be a planning session to fit all work into the capacity of the organization and allot the men and equipment, at least one day in advance. Fourth, there should be a follow-up system to see that the job is completed as requested and to close the job order if complete. There can be and are many variations and additions to thesse elements, however, there are too often a lack of one or more of the elements resulting

in confusion, wasted time, lack of cooperation, and appreciable reduction in work accomplished. Successful daily planning is the necessary first step toward not only economy, but also more accurate weekly, monthly or semi-yearly planning for budget predicting.

Standardization

Standardization has been a sadly neglected means of effecting economics in the refinery until fairly recently. Some plants have made good progress along the lines of standardization, but it is probable that these are isolated instances and quite in the minority. Standardization itself is a painful work to the purchasing and sales departments; however without even arousing their dander, it is possible to make great strides in the right direction. Coming under the classification of material standards for instance, one item alone will effect appreciable savings. The reduction to a minimum of the number of various diameters and lengths of exchanger tubes will permit reduction of stock items and quantities, as well as tools and spare bundles. Insofar as possible, the installation of standard equipment such as pumps, motors, hoists, tools, etc., will greatly assist in a reduction of spare part stocks and time required for repairing equipment.

Somewhat more intangible but none-the-less resulting in appreciable savings is the standardization of procedures. Under this classification would be encountered such items as the procedure of handling job orders from inception through approvals, design, planning, priority and scheduling, doing the work, following up, closing and accounting. The standardization of procedures for requisitioning, purchasing, expediting, engineering and metal inspection, capital expenditure requests and investigation, accounting, record and countless others all lead to improvement and economy. The setting of standards of accomplishment in production-type industries has been carefully studied and determined to a close degree of accuracy. By this means it is easy to test suggested improved procedures by checking results against the previous method. Results are usually reported in terms of man hours or dollars and can be projected into the future to determine total expected savings over a period of time. In the maintenance of refinery equipment, however, there are no two jobs exactly alike or occurring under exactly the same circumstances. It is difficult to set standards of performance and therefore difficult to determine the value of possible improvements. This needs much more study and review in order to come to any conclusions as to a best method of control of refinery maintenance work.

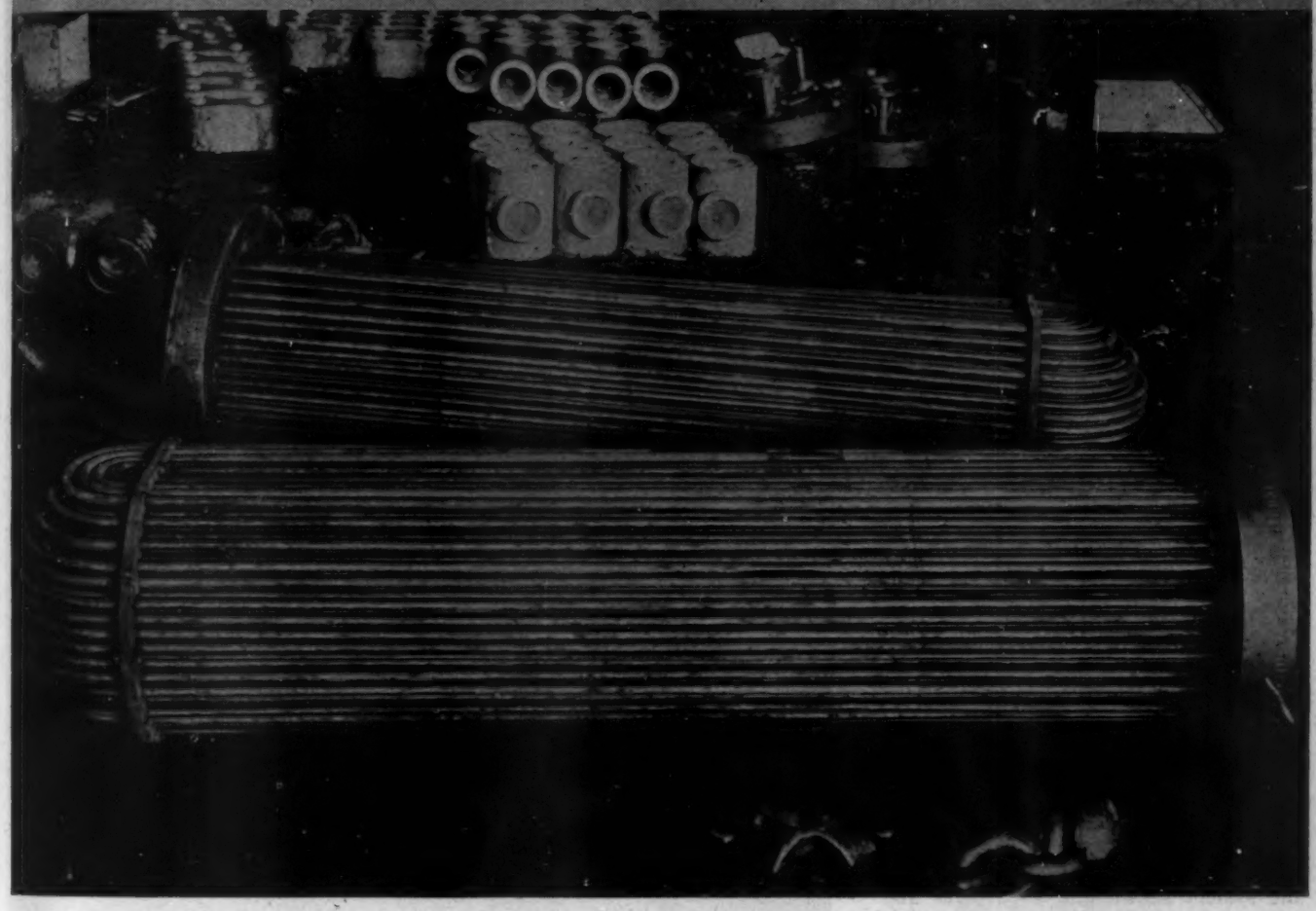
A necessary part of this control, however, is an accounting system designed to provide the supervisor with maintenance and construction cost figures of a nature that can be analyzed. It is also believed that an aid in this analysis would be the charging of actual time on the job to the account, and all other time to a general account. If nothing else, this would at least bring to management's attention the amount of non-productive labor being paid for each day and would undoubtedly prove surprisingly large. This is not a fault of labor, but inherent in a business having large areas to cover, and costly time is required for moving men and materials. The methods, however, are certainly open to improvement. Newspapers record that labor has sued a number of companies for portal pay amounting to some $6 billion representing employes' time to and from the gate and his place of work. What amount could be assigned in the oil industry for men getting to and from the varied and usually distant job locations several times each day! It is quite possible that if facts were known, it would be easy quickly to pay out a motor scooter or bicycle for each and every maintenance man in the plant. This is figuratively speaking, of course, but facts are not presently forthcoming for supervisors and management's review. Standardization should, however, provide a means of gathering the facts for economic control of maintenance work.

Review and Improvement

To review and improve the methods and procedures is, of course, the constant goal of the industrial engineer. Reviewing the results provided by the cooperation of the entire organization in planning and carrying out the work will give light on lines of attack for continuously improving the standards. Depending upon one individual or small group of the company for all improvements would produce negligible results. The provision in the organization for a coordinated handling of problems and suggested improvements, however, and with emphasis on the questioning attitude by all from management on down, would indeed result in economies of a magnitude to be appreciated. The bettering of methods and improvement of standards then is the end result or goal for which the ground work of organization, cooperation, planning and standardization is laid. Perhaps this should not be termed "end" result, however, since organization, standardization and improvement are not set or finite but must continually grow and develop to meet the times, conditions and personalities involved. Rather than as Frederick Taylor, the father of modern industrial engineering stated, "There is always a best way to do anything," it is believed that there is always a better way to do anything. The questioning attitude by a curious and imaginative mind should result in the improvement of almost any of the procedures of refinery maintenance, if the facts are available. This does not mean that the improvement is the best method, but that it is a better method in light of available knowledge.

Here then are the basic principles of industrial engineering by which the major production industries of this country have reduced their costs to increase margins and meet heavy competition. It is nothing new whatever, and has been tried and proven for many years, only awaiting the acceptance of those who seek progress and improvement. The extensive use of these tools in the refining industry would do much toward not only reducing costs but also toward further improving the working conditions in an industry already well along the road toward top public approval.

WATCH OUT FOR CHANGED CONDITIONS



SOMETIMES a condenser will give years of service, only to fail quickly after re-tubing with tubes of exactly the same composition. When this occurs it need not be a mystery; very likely operating conditions have changed over the years.

Take the case of a condenser using brackish water as a coolant. In 13 years of service less than 100 tubes failed per year, out of 7,400 tubes. Then the rate of loss rose rapidly. Re-tubing with Admiralty tubes, which had been used in the original installation, did not check the rate of loss, which continued to be unacceptably high. Laboratory studies of failed tubes showed crescent-shaped grooves in the tube walls. These were the result of a severe local impingement type of erosion-corrosion, due to disturbed flow around small particles (scale or debris) which had attached themselves to the walls. Older tubes showed the same effect, but not so markedly or destructively. The conclusion was that the load on the condenser had been raised, increasing the effects of turbulence, debris, and air entrainment.

With 1-inch O.D. tubes, turbulent or eddy flow starts above 2½ feet per second; a spot check showed that water velocity was 6½ feet per second. Here was complete confirmation of the laboratory report. The recommendation: substitute 2% aluminum brass tubes, since this alloy forms a highly protective erosion-resistant film in brackish waters much more readily than Admiralty Metal.

If the velocity of the coolant is around 6 foot per second, you can anticipate severe erosion problems. Under such conditions, Revere Revalon (aluminum brass) tubes are indicated.

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OPERATION HOW TO DO IT MAINTENANCE

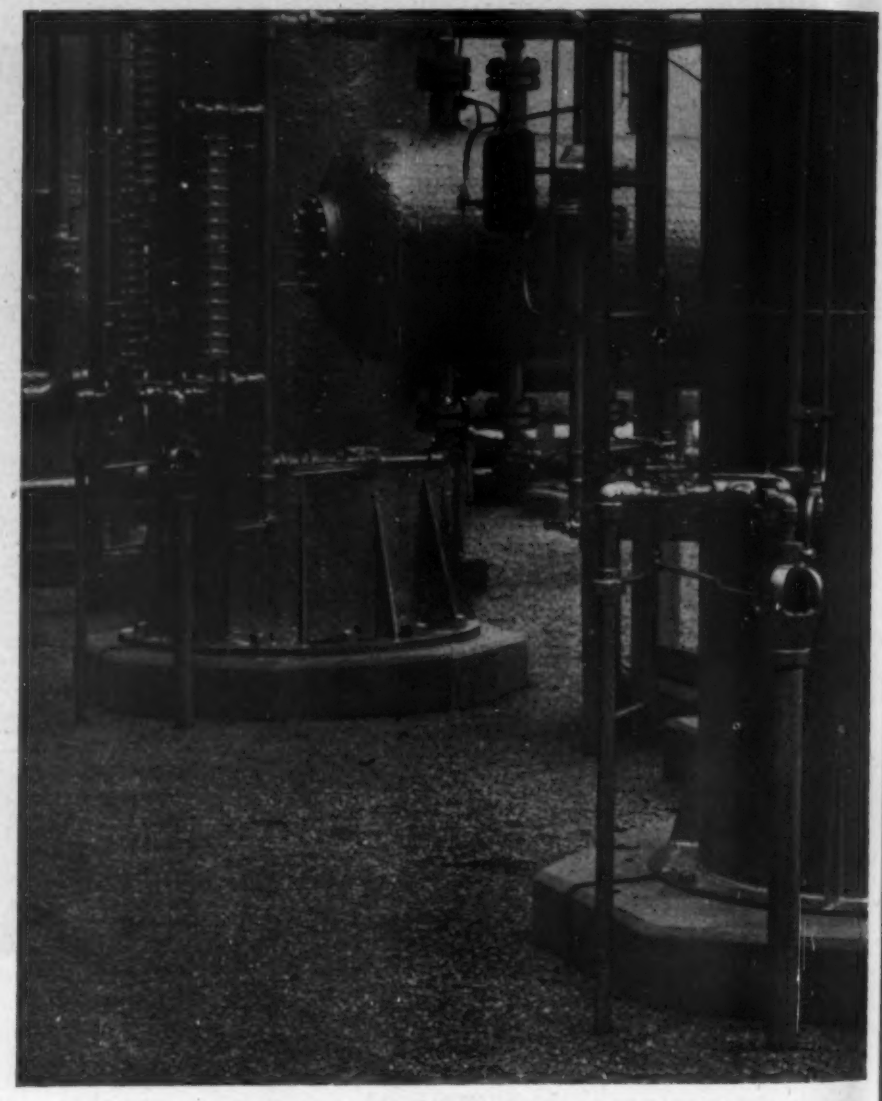
HOW TO—

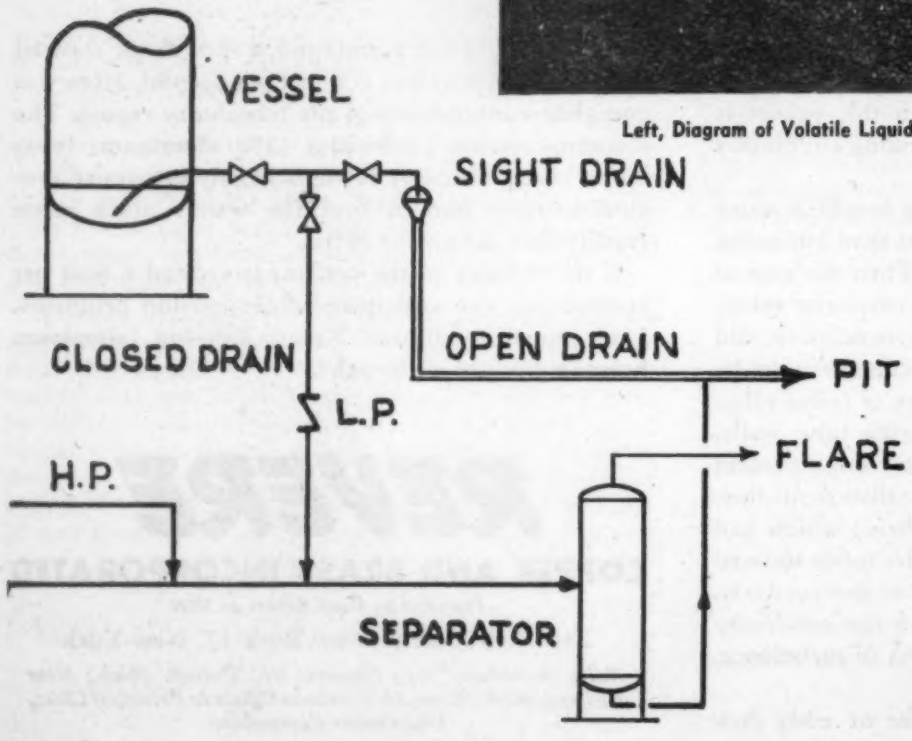
Eliminate Hazards In Draining Volatile Liquids

A method of draining pressure vessels containing volatile liquids that is rapidly coming into extensive use in gasoline and cycling plants calls for use of a closed drain and a sight drain system. The sight drain permits the operator to watch a small portion of the liquid being drained from the vessel without endangering himself or the plant, and closed drain removes the liquid from the vessel. When the sight drain indicates that the liquid has been drained from the vessel, the main valve is closed and then the sight drain and closed drain valves are closed. The sight drain permits the operator to check vessels not equipped with gauge glasses for liquid, also.

If the closed drain line is connected to a low pressure vessel and high-pressure vessels are drained into the same header, check valves are used to prevent backflow into the low-pressure piping. All liquids flow to a separator where gas is taken overhead to the flare and the liquids flow to the pits for skimming and disposal, as shown in the diagram.

The photograph of an installation of the system shows that the valves and sight drain are at a convenient height for the operator. The sight drain lead is ⅜-inch pipe, which limits the flow to a small stream.





Left, Diagram of Volatile Liquids Drain. Above, Plant Installation.

HOW TO—

Simplify Handling Gas Odorant Injection

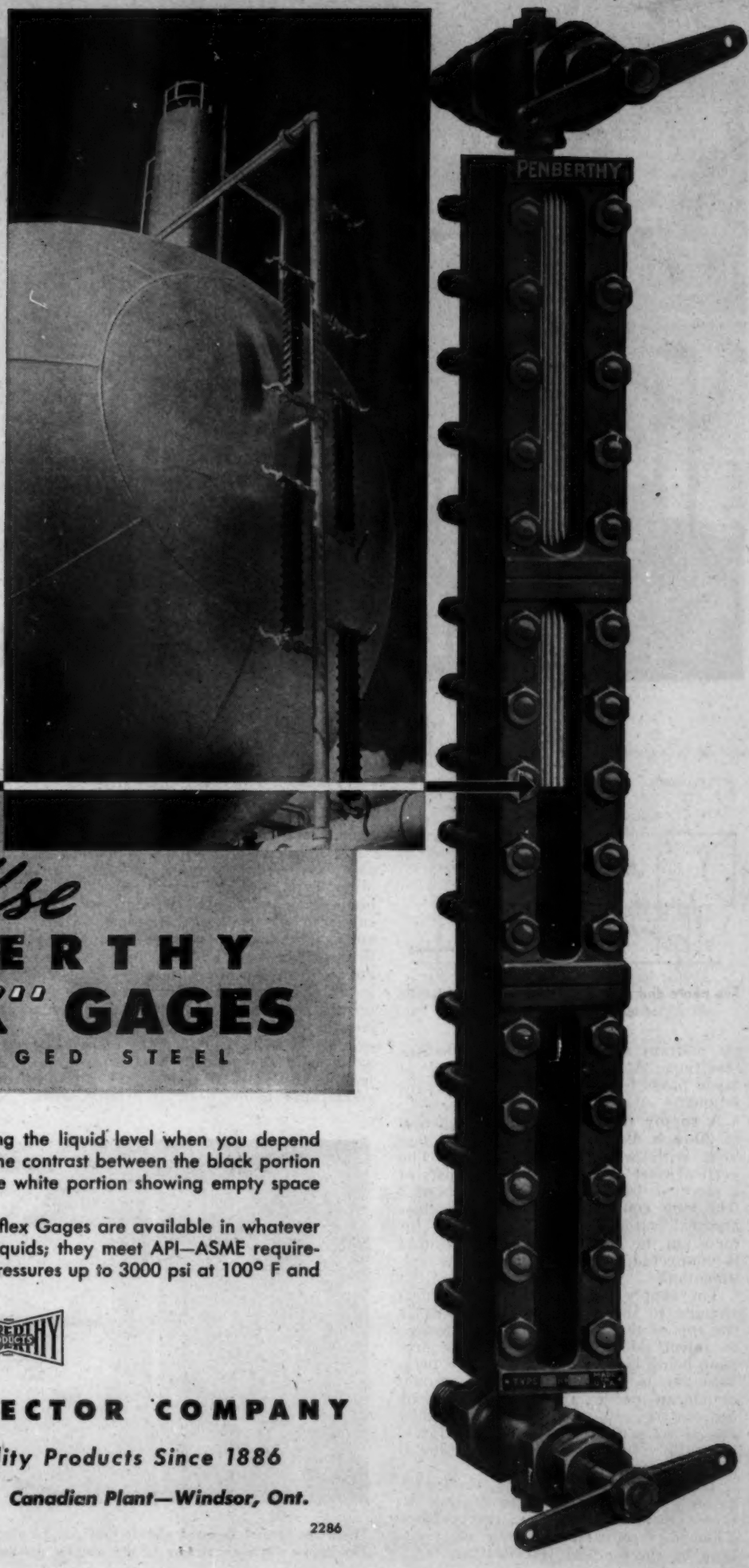
ODORANT injection into butane and propane streams for tank truck loading has been simplified by the method and equipment designed and installed by one cycling plant operator. The method eliminates handling small containers of

WHEN YOU MUST

BE SURE

OF THE

LIQUID LEVEL



EMPTY SPACE SHOWS WHITE

BLACK SHOWS LIQUID

Use

PENBERTHY "REFLEX" GAGES

DROP FORGED STEEL

There can be no error in reading the liquid level when you depend upon Penberthy "Reflex" Gages. The contrast between the black portion of the glass showing liquid and the white portion showing empty space is sharp and unmistakable.

Penberthy Drop Forged Steel Reflex Gages are available in whatever lengths required and for various liquids; they meet API—ASME requirements and are recommended for pressures up to 3000 psi at 100° F and 1000 psi at 1000° F.

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HOW TO—

Muffle the Exhaust On a Vacuum Column

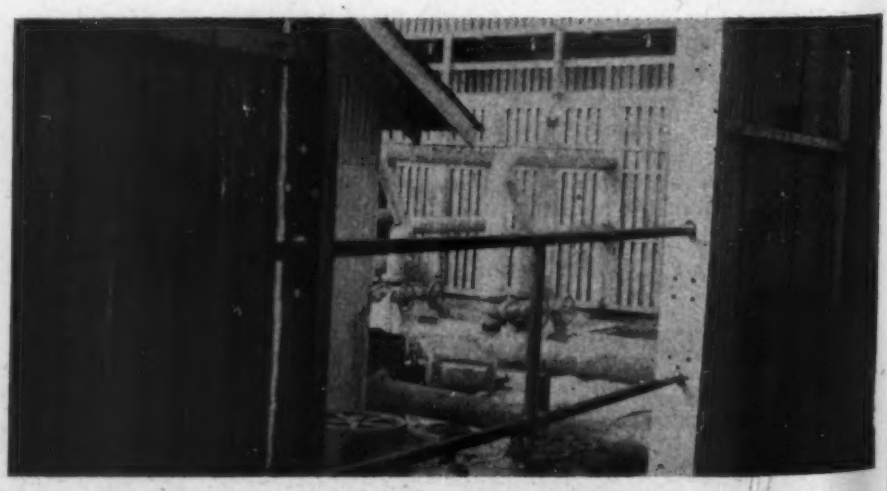
TO INSURE quietness, Leonard Refineries, Alma, Michigan, muffles the exhaust outlet on its vacuum column. The muffler is made by using an oil drum reinforced with a cross bracket for connecting to the exhaust stack. Inside is a perforated pipe surrounded with steel wool and lathe turnings, which absorb noise. (See photo at right.)

Muffler Mounted on Vacuum Column.

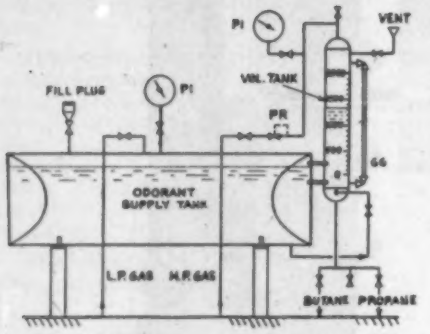
HOW TO—

Guard Against Hazard Of Open Doors

DURING the building of some engine rooms, doorways open out over pipe lines, and not to stairways as other doors are made. To prevent men from automatically leaving the building through such openings, several different kinds of guards are used. One may be a simple chain hooked at each end, and must be unhooked before a man can pass. Another type, slightly more effective, is made by using two horizontal pipe bars connected by a vertical nipple to stiffen and discourage a worker's squirming through between the two barriers. Holes cut in the door jams permit sliding the guard in either direction. It may be removed entirely if the bars are cut to a length which permits slipping into first one set of holes and then the other. The same type guard may be used on doors leading to the pit section of, say, a pump room built below floor or ground level.



There are several types of guards that can be placed across doors, left open for ventilation, etc. The above photo shows one of the simpler devices for effectively meeting this common hazard.



Top photo and diagram show installation details of gas odorant injector.

the odorant and the hazards and waste resulting. Also, accurate metering is made possible in accordance with regulations.

A supply tank was built of a section of 20-inch diameter pipe about 10 feet long with welded saddle heads. The vertical riser or volume tank consists of a piece of 4-inch diameter pipe about 3 feet long equipped with a gauge glass and calibrated in units of 100 cc. for metering the odorant. A small manifold is connected to the bottom of the volume tank.

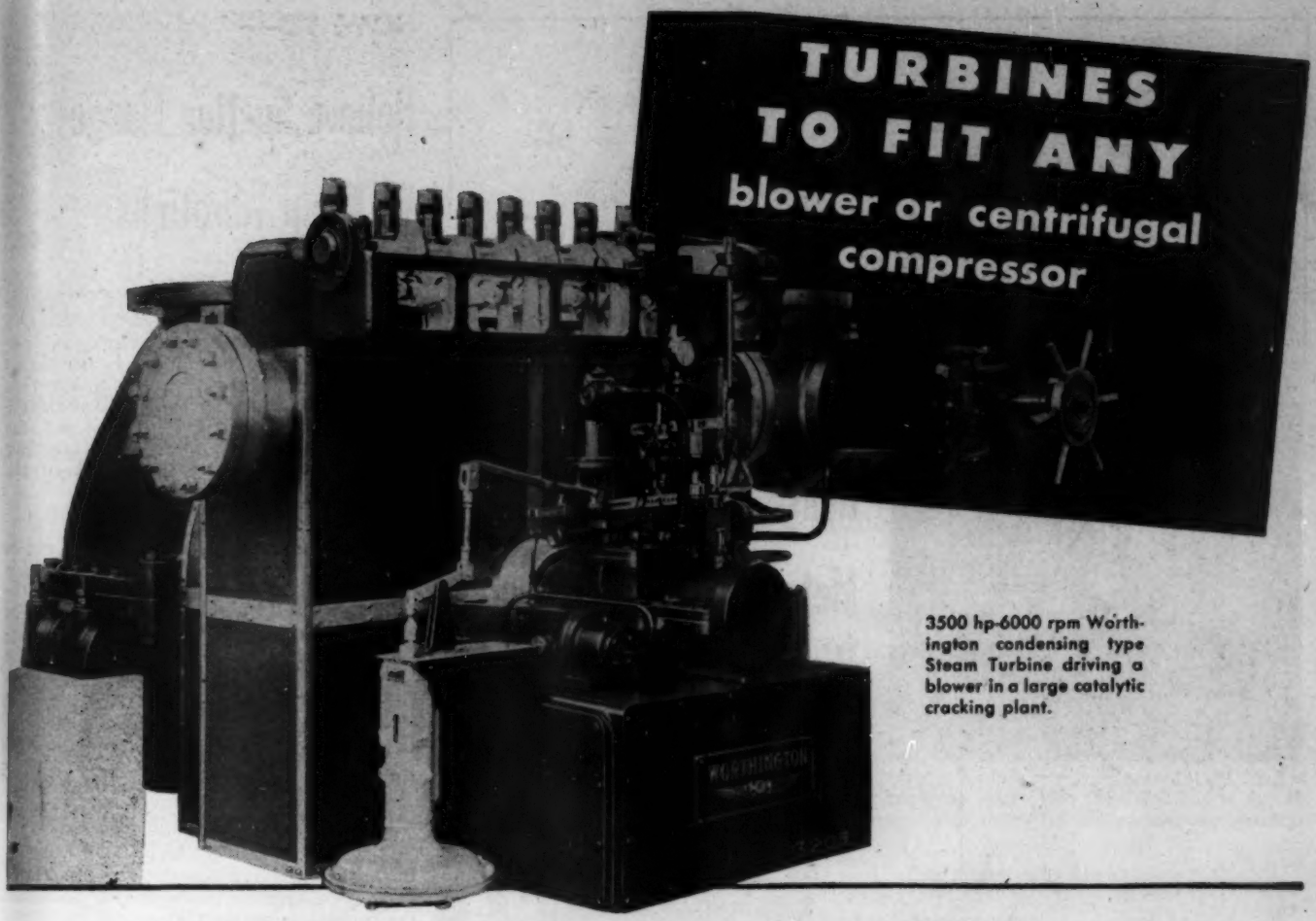
The supply tank is filled from drums shipped to the plant at the fill plug in the top of the tank. When it is desired to inject odorant into butane or propane being loaded, a supply of low pressure gas is used to force the amount of odorant needed from the supply tank up into the volume tank. High pressure gas is then used to force the odorant from the volume tank into the butane or propane stream being loaded.

To reload the volume tank, the supply of high pressure gas is shut off and the tank vent opened to release the pressure. Then the tank is refilled from the supply tank by the method described above.

HOW TO—

Operate Instruments With Gas Pressure

GAS for instrument operation in gasoline and cycling plants has become a conventional practice. The difficulties arising from the use of gas is the obtainance of a continuous supply at constant pressure, and free of moisture and condensate. There are various systems in use for achieving this objective, one



3500 hp-6000 rpm Worthington condensing type Steam Turbine driving a blower in a large catalytic cracking plant.

A 20,000 hp Worthington Steam Turbine is now being built for a centrifugal compressor drive

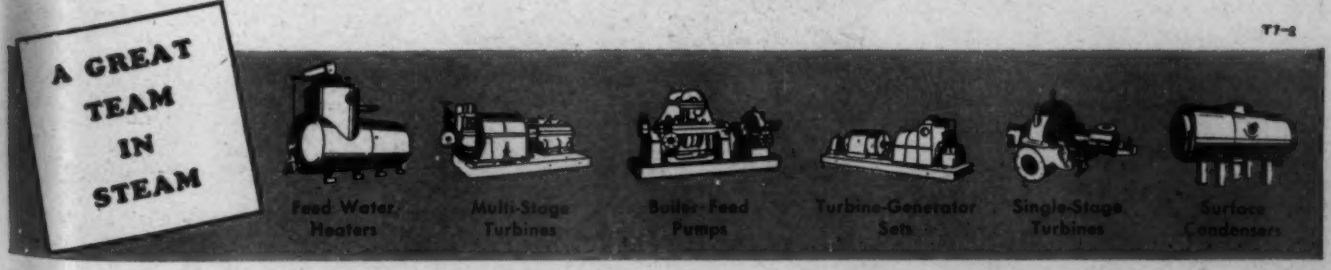
More and more refineries are getting more horsepower from less steam, because their blowers and centrifugal compressors operate at high efficiency with Worthington Steam Turbine Drives.

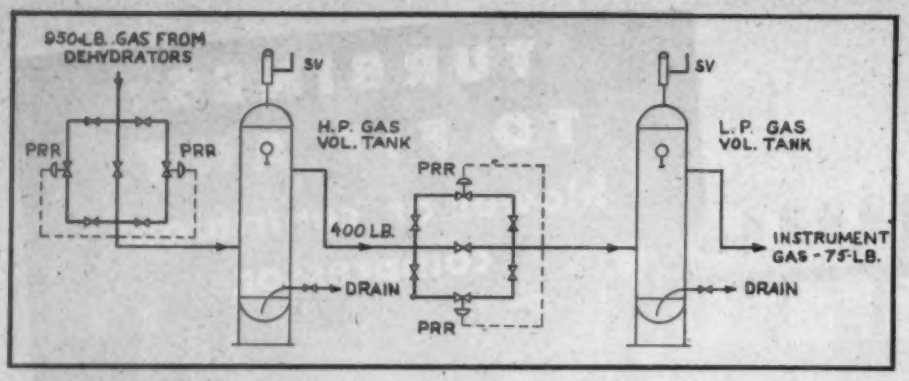
Whatever the type your plant demands...straight condensing, straight non-condensing, bleeder, mixed pressure, mixed pressure bleeder, low pressure or high back pressure.. there's a Worthington Turbine unit available. Worthington engineers, drawing on their rich experience in developing blower and compressor drives, offer you the variety of frame sizes that assures the *right* unit for *your* requirements.

For further proof... in steam turbines as in so much other equipment . . . *there's more worth in Worthington*, write for information. *Worthington Pump and Machinery Corporation, Steam Turbine Division, Wellsville, N.Y.*

WORTHINGTON

T7-2





Sketch at top and lower photo show details of utilizing gas pressure for instrument operation.

of which is illustrated in the accompanying sketch.

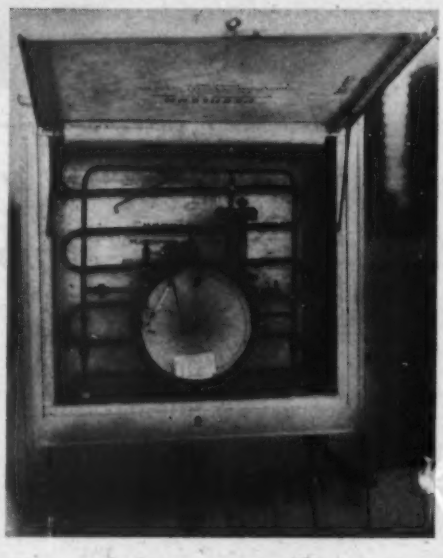
Dry gas at 950 pounds pressure is taken from the plant residue dehydrators through a dual pressure reducing regulator system and a high pressure volume tank. The pressure is reduced to 400 pounds and then flows through a second pressure reducing system and low pressure volume tank in which the pressure is reduced to 75 pounds. Individual pressure regulators on the instruments reduce the pressure to 15 pounds for instrument operation.

When the plant's absorbers are not in operation some distillate is collected in the volume tanks due to pressure reduction. In addition, regulator performance appears better with the use of volume tanks between stages.

HOW TO—

House and Heat Meters in Cold Weather

THE flow meter shown in the accompanying photograph is housed in a somewhat unusual shelter that is clamped to the flow line on which the meter is used. In cold weather the housing is heated by exhaust steam passing through the tubing seen in the rear of the meter.



Efficient Meter House.

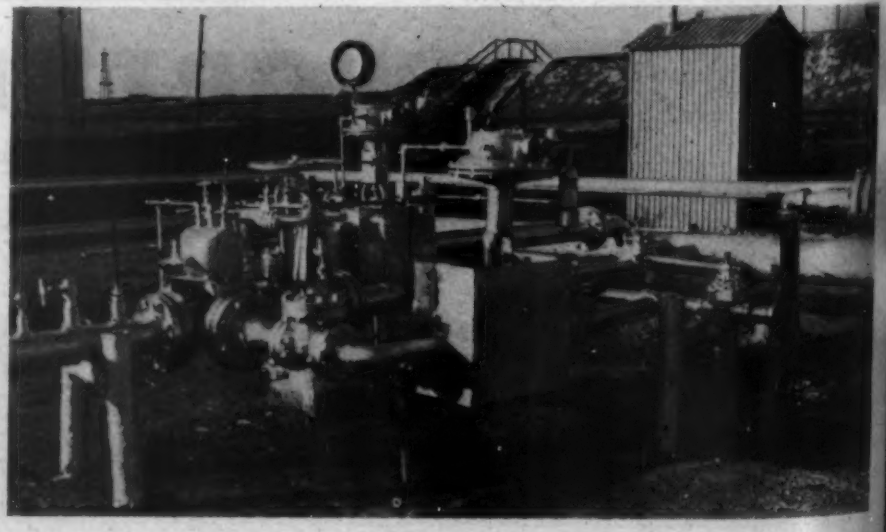
Doors front and rear of the weatherproof housing with double braces to hold them in open position, and the large size of the housing permit easy access to the meter for inspection and repairs. Each door is equipped with a hasp for locking.

During hot weather either or both doors may be propped open and housing serves as a shade and rain shelter.

HOW TO—

Heat Valves With Hot Water

IN A PLANT where steam is not used, hot water from engine jackets is employed to maintain a temperature high enough on the valve bodies to prevent freezing. An open box affixed to the pipe line connected to the valve body completely surrounds the part of the instrument to be heated. A supply line from hot water overflow in the engine room leads to the boxes, and a drain line vents the overflow to the hot water pit. (See photo at right.)



HOW TO—

Relieve Suction Flange Of Pump Vibrations

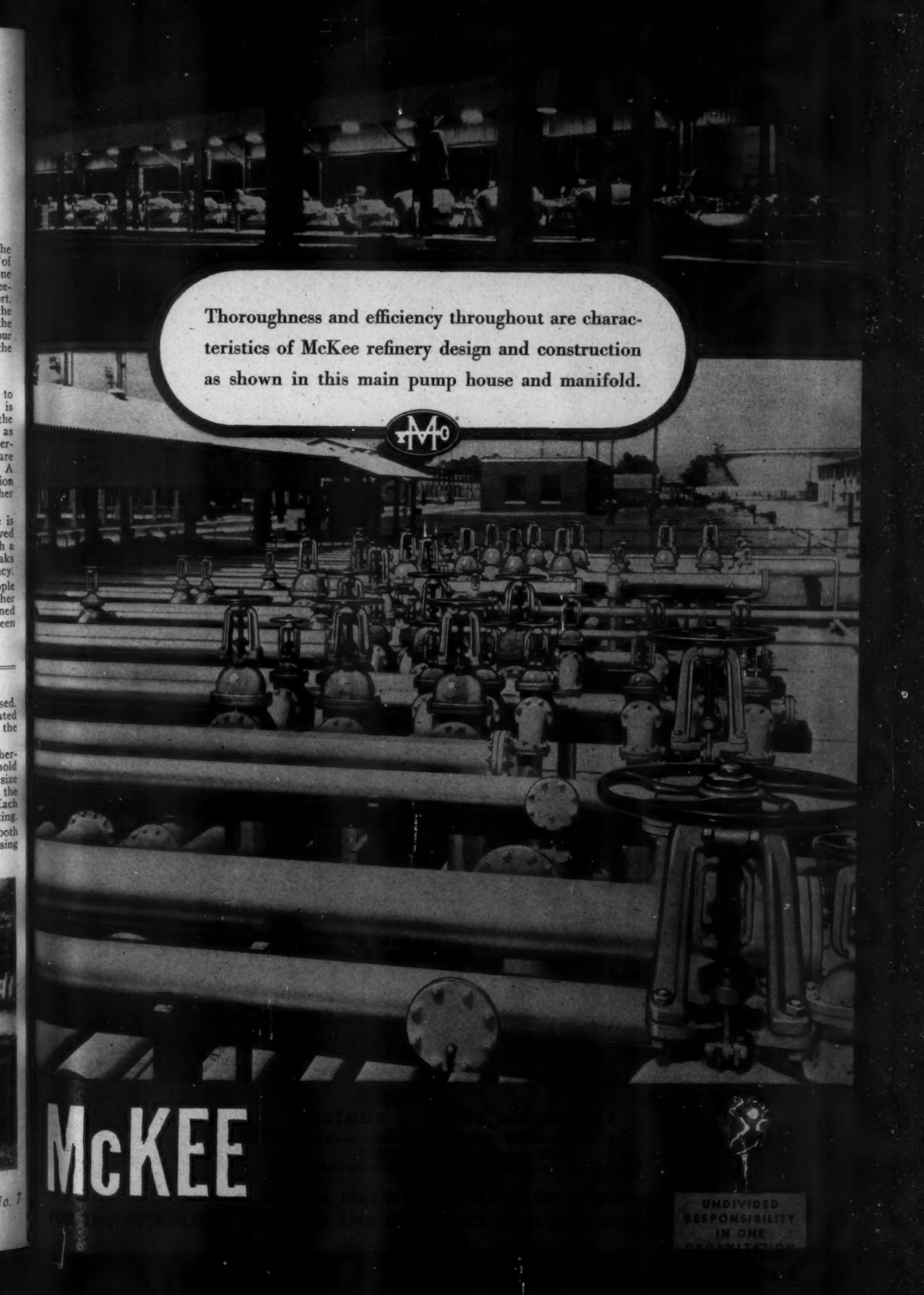
TO RELIEVE the flange joint at the suction chamber of the mud pump of vibration and consequent strain, one contractor utilizes the extra heavy three-inch priming line as auxiliary support. The priming line crosses through the pump skid some three feet from the face of the pump, and lies some four inches below the nearest point in the suction.

Installation Details

A saddle of heavy boiler plate, cut to fit the circumference of the suction, is welded to the priming line and the flange bolts then pulled up as tightly as possible. After the pump has been operated a few days the flange bolts are gone over again and all slack taken. A light bead is then run between suction nipple and saddle, tying the two together rigidly.

All vibration of the extended pipe is thus snubbed, and the gasket relieved of twisting and cramping which, with a free suction, might result in air leaks and consequent drop in pump efficiency.

If, for any reason, the suction nipple must be removed, the bead on either priming line or suction nipple is burned off, and replaced after repairs have been completed.


Thoroughness and efficiency throughout are characteristics of McKee refinery design and construction as shown in this main pump house and manifold.
McKEE
UNDIVIDED RESPONSIBILITY IN ONE ORGANIZATION

Tight Refining Situation Likely To Continue; Steel Big Problem

FRED VAN COVERN, Director of Statistics
American Petroleum Institute

ONE OF the first things that came to mind in contemplating the preparation of this paper, is the very complete group of operating statistics available to the petroleum refining industry. I believe that the information currently available to you is as timely and complete as in any industry, anywhere. Not only does the Bureau of Mines of the Department of the Interior compile and release a detailed group of annual and monthly summaries of operations, but important weekly figures are available through the American Petroleum Institute. The present API report is the result of years of effort to provide those interested with an up-to-date and reliable statistical statement on current operations. It is published each Wednesday afternoon and released through all national press wire services, and through the trade press. The items shown include crude run to stills, principal product output during the week, and inventories of those products at the close of that week. Currently refiners operating about 87 percent of the total capacity of the country contribute to this report. The portion of the industry participating should increase shortly, if the response we have had to a recent invitation to those not now reporting, that they also join in this effort, is a clear indication of the reception accorded these figures.

There is one point in connection with that report which I again should like to try to clear up, and that is the erroneous impression that some people still seem to have, that we report only for the portion of the industry that sends figures to us. True, we do not get detailed information from all refining companies, but through a somewhat involved procedure which we call a differential method, we do include thereby in the totals shown, an estimate covering non-reporting refiners. This makes our figures directly comparable with those later published by the Bureau of Mines. How successful that method has been will immediately become apparent through comparison of the two sets of figures.

HERE IS A summary of the facts and opinion presented by Fred Van Covern, at the API Division of Refining mid-year meeting held in St. Louis June 2-3:

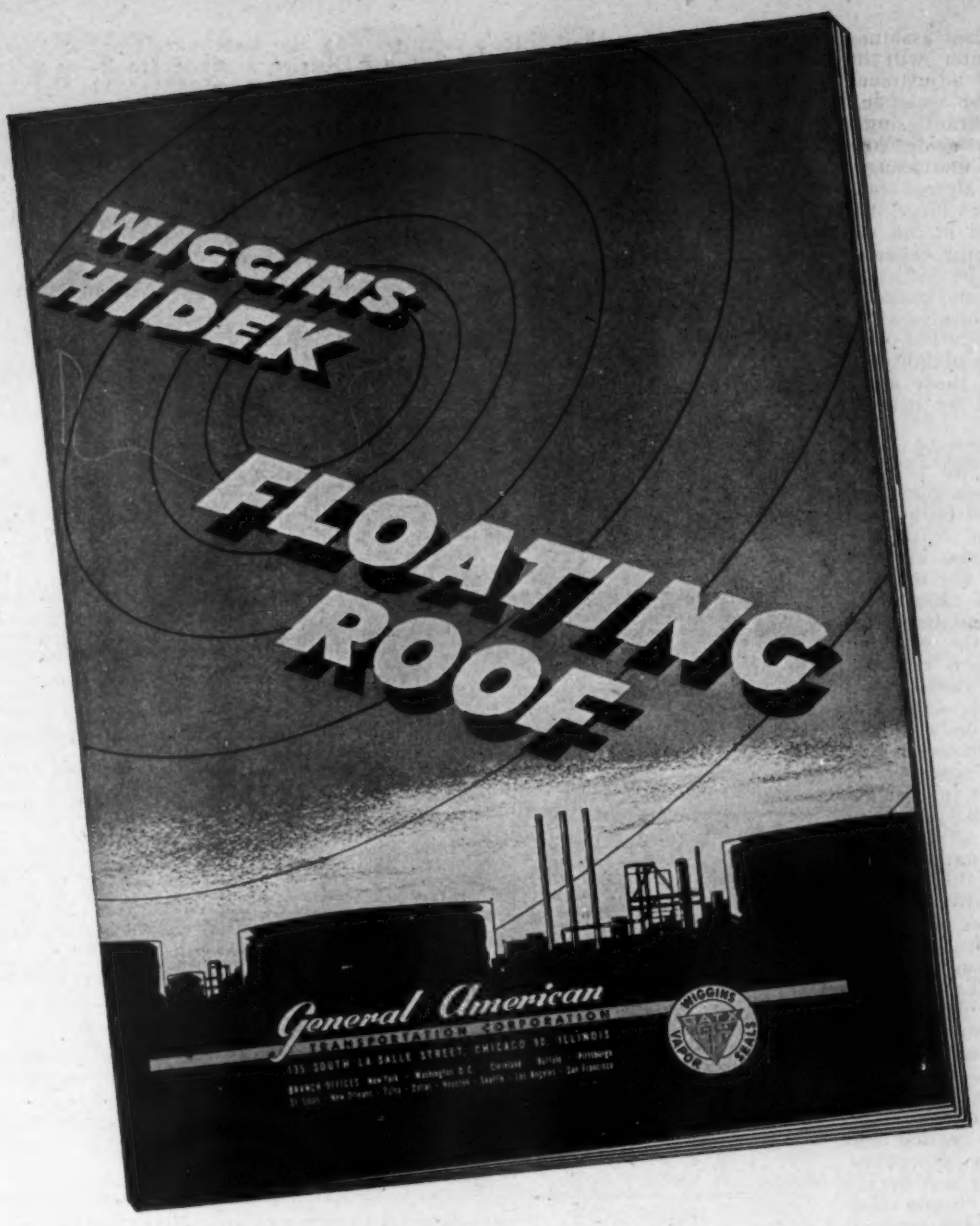
1. Demand for products is at an all-time high rate and the long-term trend is up.
2. Crude oil producibility is great enough to cover the country's current requirements and those of next winter under normal weather conditions. There doubtless will be a number of cases, even so, where given companies will be short.
3. Refinery capacity is currently sufficient in all areas. However, the amount of new construction being done is small in comparison with the probable trend of demand. High costs, shortages of steel and other materials are doubtless discouraging factors.
4. District 2 needs more crude. Crude and product stocks are lower than seasonally desirable and must be built up at a high rate this summer. Otherwise the situation next winter will be difficult. Uneconomic, costly railroad movements are already taking place. Local areas of shortage may arise at any rate—particularly if the winter is colder than normal. Transportation is the district's big problem.
5. Much depends on whether new lines into the area can be completed and operating soon enough. Operators will, even so, have to resort to increased use of tank cars and barges. Speeding up of drilling campaigns is also essential.
6. In other areas storage capacity will be taxed to the limit. Householders in the northeastern section of the country, as well as dealers and distributors, could relieve industry storage by having their own tanks filled this summer. Deferred billing might act as an incentive to do this.
7. Subnormal temperatures next winter, particularly if there is no recession in business, would bring about added difficulties. Some inefficient and uneconomic capacity would have to be brought into use. Given areas and even companies will be short.
8. Labor disturbances curtailed refinery runs more than 12,000,000 barrels from January 1 to May 26, and some of these costly strikes are continuing. The supply of products has therefore been reduced by close to this amount.
9. The transportation outlook for the East Coast would be greatly improved were the present general agency arrangement now in effect through the U. S. Maritime Commission, continued by legislative Act beyond June 30, or some other arrangement created to take its place.
10. Beyond March 31, 1948—more of the same everywhere; still no apparent surpluses. Production, refining, transportation and marketing facilities, all will be incapable of carrying the load unless enlarged. Time, increased personnel, large expenditures and equipment are necessary to rebuild, improve and expand. I am sure, however, that the industry with its brilliant background of accomplishment can do the job if it can obtain the necessary supplies of steel and other materials.

High Rate Must Continue

Incidental to the information just referred to, because we think it interesting and informative, are the refinery capacities reported to the API. These we compile and use in order to indicate the percentage rate at which the plants of the country are being operated from time to time. The present rate is high and you know that operations must remain high if enough products are to be available.

In that connection, I should like to refer to the recent report of the Economics Advisory Committee of the Interstate Oil Compact Commission presented at Birmingham, Ala., and particularly the references to demand, crude oil production and refinery runs:

"The committee estimates that the 1947 petroleum demand in the United States, including about 400,000 barrels daily of exports, will be 5.7 million barrels daily, an increase of 7 percent over the demand last year. Some allowance has been made for a slight recession in business activity during the latter part of 1947. The effect of a business recession on petroleum demand this year is anticipated to be small because there is generally a lag in the influence of such recession on petroleum demand and because of the upward trend created by new oil-using equipment, such as automobiles, trucks, tractors, diesel engines, and oil burners. If a sharp business recession develops soon, or if next winter is warmer than normal, demand may be less than estimated in the present forecast. On the other hand, demand may be higher if business activity continues at present levels or if next winter



One of the most significant developments in the handling and storing of petroleum products, The Wiggins Hidek Floating Roof, is now presented through the medium of three-dimensional phantom drawings—with full explanatory text.

The bulletin explains fully how breathing and pumping losses are reduced to a minimum and product quality retained by:

Hermetically sealing the liquid surface with triple seal protection.

Permitting the relatively small volume of vapor intentionally trapped beneath the roof to expand without venting.

This bulletin contains information vital to every phase of management, information which the executive concerned with the efficient storage and marketing of petroleum products can use to reduce losses and increase profits.

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WIGGINS BREATHER ROOF

WIGGINS DRY SEAL LIFTER ROOF

WIGGINS DRY SEAL GAS HOLDER

is unusually cold. The forecast assumes that the weather next winter will be normal, and is subject to adjustment in case of colder or warmer weather."

Perhaps the most significant single thing indicated in that report aside from the expected continuation of increasingly high levels of demand is the almost complete disappearance of former large surpluses. Times have changed in the petroleum industry. Refining capacity would, however, appear to be sufficient under normal expectations and there is still some crude oil available above the current rate of production. The real question is the economic availability of what surplus still exists to those areas in short supply as limited by present transportation facilities.

In translating the expected level of demand into domestic crude oil production requirements and necessary runs to stills, the Advisory Committee arrived at the conclusion, "that 5 million barrels daily (crude oil production and runs) will be required for the next 12 months to meet demand as estimated," and from the detailed tabulations attached to the report and the working papers we find that average required runs to stills during the coming six months are 5,035,000 barrels daily and probably 5,080,000 barrels daily during the first quarter of 1948. The report further states that, "it may be noted that a small variation of 2 percent in demand means over 100,000 barrels daily, a quantity substantial enough to affect many consumers in the present situation where the industry may not have the capacity to make up a deficit of this magnitude."

Let us first consider these figures in relation to available refining facilities and recent actual levels of runs to stills. The capacity figures in Table 1 are those of the API strengthened recently through questionnaire sent to the industry. We also took into account all other information available to us. The definition used was that of the Bureau of Mines: "the maximum daily average throughout attainable under normal conditions with allowance for downtime, cleaning, inspections, repairs and breakdowns. Normal conditions imply contemplated grades of crude for contemplated types of products finished to the extent customary to that refinery."

True Capacity Picture Difficult

You will agree that no single figure can give a true picture of refinery capacity because the latter is bound to be greater for certain types of crude than for others. Daily capacity will also vary depending on whether a plant is being operated for maximum gasoline or high yields of middle distillates and residual fuels. In some cases, notably the East Coast, it will vary as the proportion of the supply of different crudes, domestic and foreign, vary in relation to the total available.

Some of the capacity included in Column 2 is, of course, of the skimming plant type, which operating by and of itself can hardly compete in making the kind of gasoline that today's markets demand. However, where high quality blending stocks are available and crude is nearby, skimming capacity can be helpful under the operating and economic circumstances which exist today. Otherwise such capacity would be useful only under emergency conditions.

The rate of crude processed was at a low level as the second quarter began, and during the four weeks ended May 17 was about 170,000 barrels daily less than the Compact Committee's calculations. Districts 2 and 3 were behind—the former doubtless because of lack of new crude and transportation with which to bring it in from other areas, as well as strikes, and the latter district mainly because of strikes. District 2 crude stocks are also showing the effects of this condition, having declined considerably during the last year. On the other hand, District 3 crude stocks have been increasing because of strikes and the Texas City explosion. Table 2 herewith brings out the runs to stills comparisons referred to.

The effects of the Texas City disaster on refinery runs were not as great as at first thought. Up to about a week ago

TABLE 1

Operating and Shut-Down Refinery Capacities vs. Required Runs to Stills

(Daily Averages in Barrels, as of March 31, 1947.)

REFINING DISTRICT	Capacity of Operating Refineries*	Non-Operating Capacity	Total Cols. 1 + 2	Runs to Stills Econ. Comm. (Jan.-Mar. 1943)	Percent of Capacity†
	(1)	(2)	(3)	(4)	(5)
1	941,700	5,500	947,200	890,000	
2	1,387,700	50,500	1,438,200	1,340,000	92/89
3	1,833,200	274,600	2,107,800	1,900,000	
4	168,500	5,300	173,800	130,000	
E. of Cal.	4,331,100	335,900	4,667,000	4,260,000	91/88
5	909,000	35,000	944,000	820,000	
U. S.	5,240,100	370,900	5,611,000	5,080,000	91/88

* On March 31, 1947, there were about 175,000 barrels daily of capacity shut-down on account of strikes which is not included in this column. It is included in Column 2—(District 1—5,500; 2—29,400, and District 3—140,000 barrels daily.)

† The figure at the left is the percent that Column 4 is of Column 3. The figure at the right is the percentage relationship as of March 8—before strikes.

TABLE 2

REFINING DISTRICT	COMPACT COMMITTEE CRUDE RUNS REQUIRED		ACTUAL CRUDE-OIL RUN TO STILLS			
	First Quarter 1948	Second Quarter 1947	Actual Average 4 Weeks Ended May 17*		Individual District Monthly Highs Since 1/1/46	U. S. High Postwar (August, 1946)
	(1)	(2)	(3)		(4)	(5)
1	890,000	880,000	904,000	(908)	889,600	849,000
2	1,340,000	1,300,000	1,261,000	(1,286)	1,269,300	1,245,000
3	1,900,000	1,865,000	1,697,000	(1,888)	1,879,300	1,861,000
4	130,000	125,000	121,000		128,400	116,000
E. of Cal.	4,260,000	4,170,000	3,983,000	(4,203)	4,166,600	4,071,000
5	820,000	810,000	829,000		806,500	785,000
U. S.	5,080,000	4,980,000	4,812,000	(5,032)	4,973,100	4,856,500
			220,000			
			5,032,000			

* During the four weeks ended May 17, a daily average of 200,000 barrels daily runs were lost on account of strikes and about 20,000 barrels daily because of the Texas City explosion.

TABLE 3

New Construction As Reported By 49 Companies

(Daily Throughput—Barrels 42)

REFINING DISTRICT	CAPACITY EXPECTED TO BEGIN OPERATING IN:							
	1947			1948			1949	
	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	2nd Half	1st Half	2nd Half
1	.....	.....	.....	.....	.....	7,000	40,000	5,000
2	.....	23,000	.....	23,000	.....	†43,000	50,000	7,000
3	4,000	20,000	.....	20,000	12,000	.....	35,000	.....
4	2,000	6,000	.....	2,000	.....	3,000	9,000	.....
E. of Cal.	6,000	49,000	.....	45,000	12,000	53,000	134,000	12,000
5	6,000	*90,000	.....	.....	.....	.....	.....	.....
U. S.	12,000	*139,000	.....	45,000	12,000	†53,000	134,000	12,000

* Includes 85,000 said to be for replacement. † Includes 15,000 said to be for replacement.

TABLE 4

Estimated Crude Oil Summary

First Quarter 1948 on Basis of Production Rate Week May 17, 1947

(Barrels 42—Daily Averages)

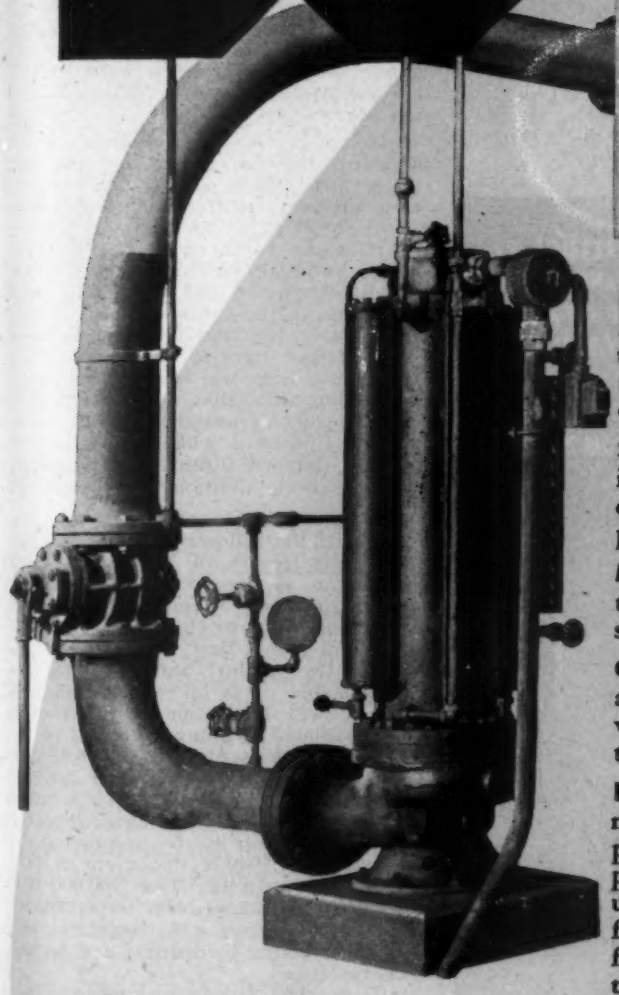
REFINING DISTRICT	API Crude Production Week May 17	PROBABLE*		Crude Used† Direct or Transferred	Approximate Availability as Runs	Crude Runs Compact Comm. 1st Qtr. 1948
		Imports	Exports			
	(1)	(2)	(3)	(4)	(5)	(6)
1	57,200	288,000	8,000	.....	.....	890,000
2	953,700	.....	46,000	10,000	.....	1,340,000
3	2,910,000	2,000	16,000	8,000	.....	1,900,000
	3,920,900	290,000	70,000	18,000	4,122,900	4,130,000
4	178,750	.....	3,000	2,000	173,750	130,000
E. of Cal.	4,099,650	290,000	73,000	20,000	4,296,650	4,260,000
5	908,400	.....	19,000	50,000	839,400	820,000
U. S.	5,008,050	290,000	92,000	70,000	5,136,050	5,080,000

* Compact Committee's report.

B.J. Stuffingboxless Pumps

NO PACKING
because there is no stuffingbox

NO LEAKAGE
of pumped liquid to atmosphere because of the seal oil system



BJ Process Type Stuffingboxless Pump, installed at Union Oil Company's Wilmington Refinery. Size: 4 x 6 x 10LL. Pumps Iso-Butane at 130° F.; 450 gpm against a 450 foot head. Several hundred BJ Stuffingboxless Pumps are in service.

For pumping costly, volatile liquids, BJ Stuffingboxless Pumps are unequalled. With these pumps, leakage to atmosphere is *impossible;* hence they are ideally adapted to pumping butane, propane, ethane and other extremely volatile hydrocarbons.

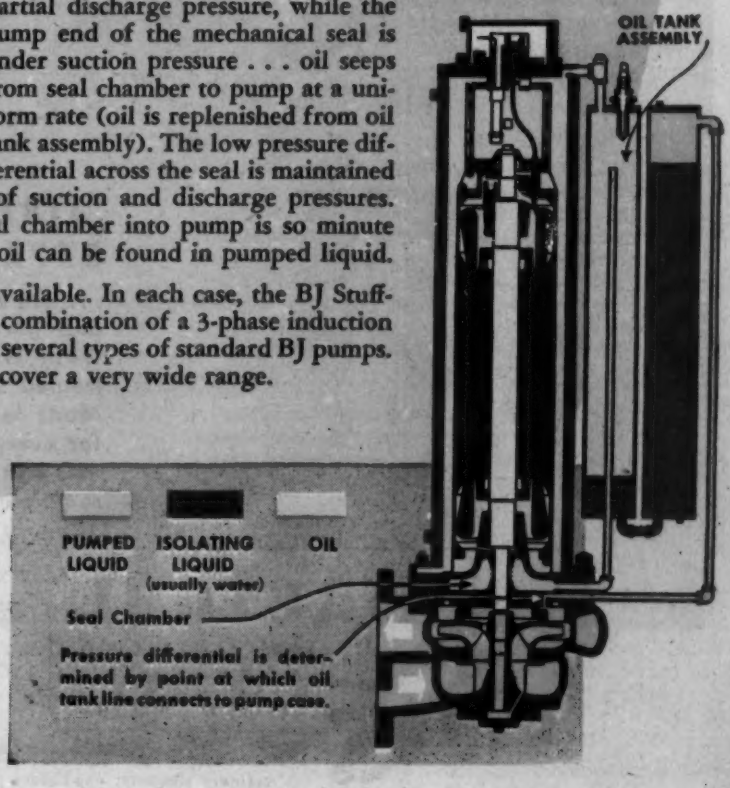
Sealed Motor is direct-connected to the pump. Motor is housed in a steel case filled with an oil of high dielectric strength. The oil provides both electrical protection and lubrication.

Mechanical Seal. A double mechanical seal, contained in an oil-filled seal chamber, replaces the stuffingbox.

Oil Tank Assembly. A two-compartment oil tank assembly holds the auxiliary motor oil supply and provides a method by which partial discharge pressure is transmitted to motor oil and seal chamber.

Fixed Pressure Differential Across Seal. Since the motor and seal chamber is under partial discharge pressure, while the pump end of the mechanical seal is under suction pressure . . . oil seeps from seal chamber to pump at a uniform rate (oil is replenished from oil tank assembly). The low pressure differential across the seal is maintained *constant,* regardless of suction and discharge pressures. Oil seepage from seal chamber into pump is so minute that no trace of seal oil can be found in pumped liquid.

Several Types are available. In each case, the BJ Stuffingboxless Pump is a combination of a 3-phase induction motor and any one of several types of standard BJ pumps. Capacities and heads cover a very wide range.


OIL TANK ASSEMBLY
PUMPED LIQUID
ISOLATING LIQUID (usually water)
OIL
Seal Chamber
Pressure differential is determined by point at which oil tank line connects to pump case.

Byron Jackson Co.

LOS ANGELES 54, CALIFORNIA

Offices in Principal Cities

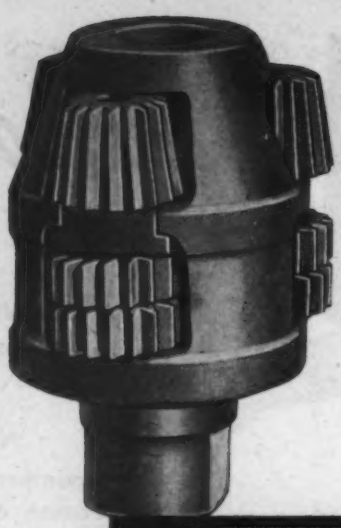
For drawings and specifications, address Dept. 168

SLIP-FIT CONSTRUCTION OF

AIRETOOL MOTORS

SAVES TIME ON THE JOB WHEN PART REPLACEMENT BECOMES NECESSARY

In Airetool Motors, all parts are ground to precision slip-fit. This permits them to be torn down and reassembled, right on the job, without special tools . . . thus effecting a substantial saving of time when part replacement becomes necessary, after long, hard use.



THE AIRETOOL P-TYPE CLEANING HEAD MOUNTED ON A HEAVY DUTY REFINERY MOTOR . . . AIR OR STEAM DRIVEN . . . FOR TUBES FROM 2¼" TO 4¾" I. D.

This cut-away view of Airetool's Heavy Duty Refinery motor illustrates the simplicity of slip-fit construction of all Airetool motors.

● In addition, Airetool Motors have a *Balanced Rotor . . . an unique Power Seal . . . and develop more power!*

The Balanced Rotor in Airetool's powerful motor eliminates friction so that all power is directed against the load.

The Power Seal assures maximum efficiency at all speeds. It maintains torque as low as 50 rpm without stalling.

Airetool Refinery motors are air or steam driven.

● **SPECIAL HEAT TREATMENT** . . . of alloy steel produces uniform grain and hardness in every working part . . . makes Airetool Tube Cleaners and Expanders last longer and cost less to operate.

AIRETOOL EXPANDERS

. . . are self-feeding and precision built from finest heat treated alloy steel. Made in every size for every tube rolling and expanding requirement.

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. . . write for bulletins on all types of Airetool refinery cleaners, expanders and accessories.

when this paper was finalized about 1.5 million barrels of crude runs had been lost. The actual loss otherwise in finished products and crude was of course much greater.

Labor difficulties have been a larger factor in the current supply situation than generally realized. At one time in May 220,000 barrels daily refining capacity was shut down because of such disturbances. (As shown in Table 2, Column 3.) Up to a week ago the total 1947 loss in crude runs was an estimated 12,038,000 barrels, and if labor had seen fit to continue work while discussing contracts, that much more crude oil would have been run this year so far, and the product supply situation helped correspondingly.

Some of this loss has doubtless been made up through processing arrangements with others, aand some may be made up as a result of increased runs, where possible, between now and when the products are needed. The fact remains, however, that supplies for important consumer and industrial areas are behind to the extent of most of this curtailment. Also the refining facilities, that will later have to be used to make it up, could otherwise have been devoted to building available supplies to still higher levels. Transportation of these additional products when they are made, to where they will ultimately be required, will also create additional problems.

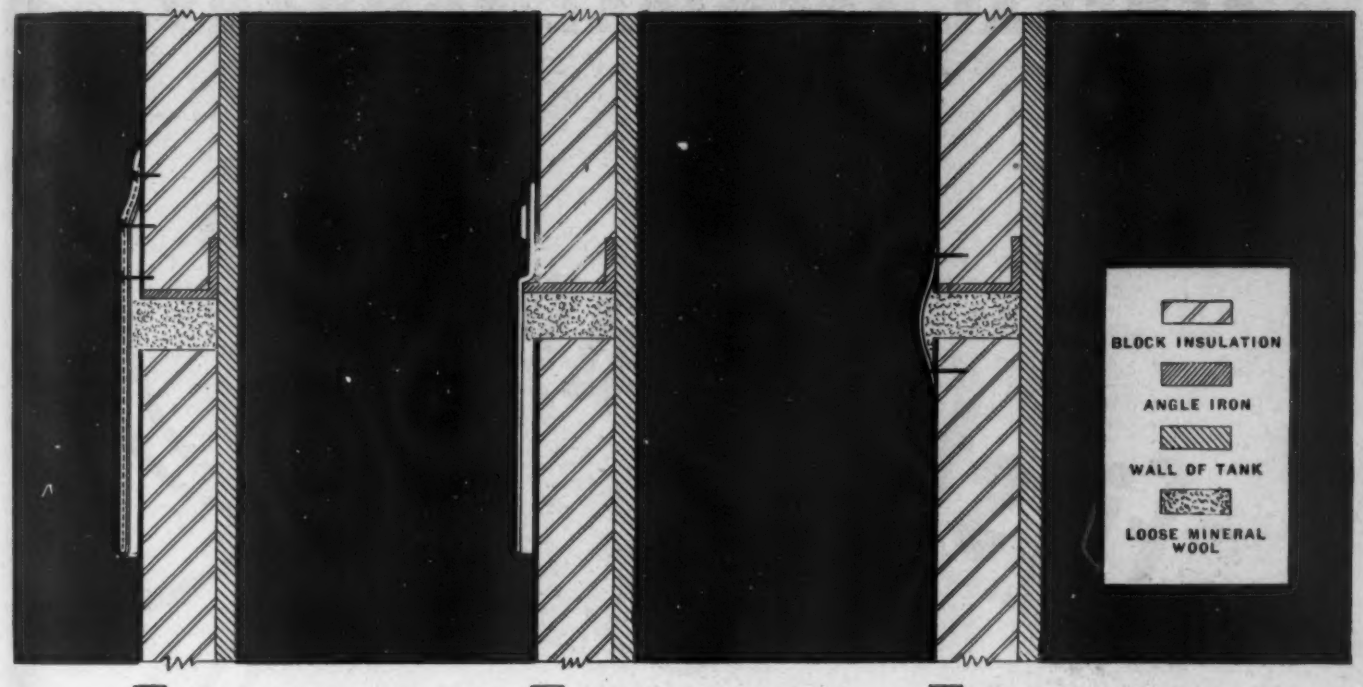
The questionnaire referred to earlier also asked the following questions: Expressed in terms of daily crude oil throughput, is your company: 1) Now constructing new refining capacity? 2) Are any additions or changes being made at present plants that will result in additional throughput? and 3) What are the probable dates on which this new capacity will begin operating? As this was completed 49 companies (out of the 60 asked) representing about 4,485,000 barrels of the March 31 daily refining capacity, or 80 percent of the total of the country as of that date, reported new construction to be completed by December 31, 1949 to the extent of 407,000 barrels daily, of which 100,000 barrels daily is marked for replacement. Table 3, (see page 136), indicates this new construction by districts and periods of completion.

Up to this point, consideration has been given mainly to the question of refinery capacity. While over-all country-wide availability would appear to be sufficient, and the same holds true in the case of the individual refining districts during the period under consideration, the amount of new capacity being constructed is surprisingly low. This is doubtless due both to high construction costs as well as to a lack of materials.

Of course, the normal development of the industry was held back during the war and the million barrel daily crude oil producibility above requirements, which existed before hostilities began, has been absorbed by war needs and an expansion of civilian demand. Materials of all kinds were short and are still short—but demand for products is higher—in the first quarter of this year, 5 percent above the wartime record demand which occurred in the first quarter of 1945. The demonstrated dependability, cleanliness and convenience of handling and using oil as against other fuels, and the large amount of favorable publicity received as a result

How would YOU weatherproof this expansion joint?

Outdoor vertical tank is held at high temperatures, has expansion joint in the insulation.



☐ Flap of weatherproof plastic, wire mesh, and roofing felt, stapled to insulation above joint?

☐ Apron or flashing of sheet metal, banded to the tank or vessel above projecting angle iron?

☐ Collar of flexible fabric saturated with weatherproof plastic, stapled to insulation above and below?

HERE'S WHAT THE ARMSTRONG ENGINEER RECOMMENDED:

The first method is comparatively expensive because it requires slow and painstaking application. Also, if the tank stands in the sun, external heat may eventually cause the flap to stick. Movement would then tear the insulation.

The third method is lowest in cost. But it does not look very neat, and the cloth cannot be so full that it will fold, or it will crack. Therefore, this weatherproofing is desirable only where the vertical movement caused by expansion and contraction is relatively slight —and where cost is a vital factor.

The second method is recommended for most jobs. Its cost is moderate, and it provides positive assurance that the joint can open and close freely without damaging the insulation. Also, maintenance is simple and inexpensive.

* * *

True, weatherproofing an expansion joint is a detail—and a fairly uncommon one at that. That's just why we're talking about it. Your Armstrong engineer, construction foreman, and craftsmen all know the importance of such details. Every "trifle" on a heat insulation job can be costly to you if it's done wrong—and it can be mighty helpful when it's handled right.

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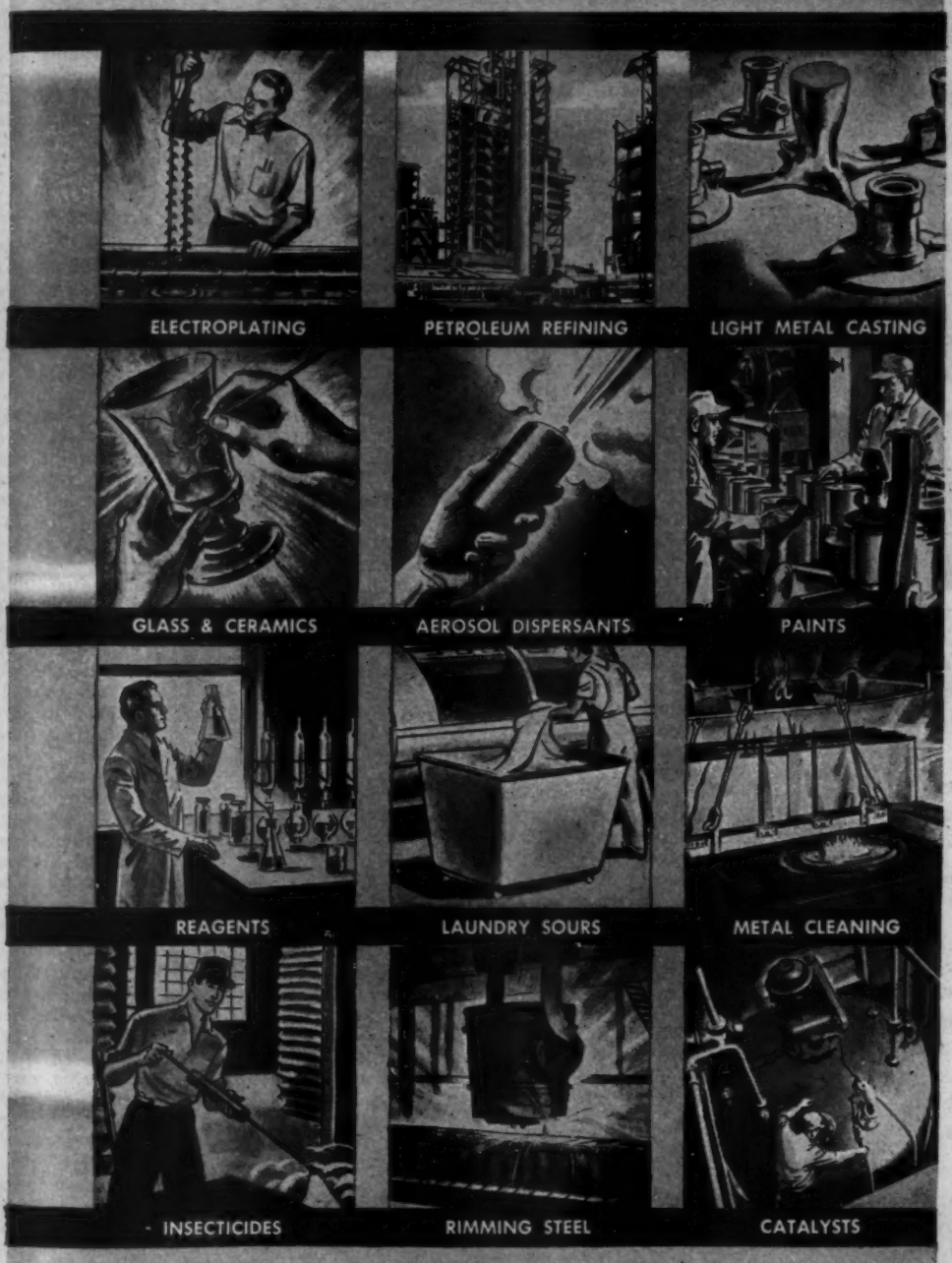

1 Alkali Fluorides

Potassium Fluoride
Sodium Fluoride

2 Metal Fluorides

Aluminum Fluoride
Antimony Trifluoride
Barium Fluoride
Cadmium Fluoride
Calcium Fluoride
Chromium Fluoride
Copper Fluoride
Ferric Fluoride
Lead Fluoride
Magnesium Fluoride
Nickel Fluoride
Strontium Fluoride
Zinc Fluoride

3 Double Fluorides

Potassium Chromium Fluoride
Potassium Ferric Fluoride
Potassium Titanium Fluoride

4 Non-Metal Fluorides

Boron Fluoride—Diethyl Ether Complex
Sulfur Hexafluoride

5 Acid Fluorides

Ammonium Bifluoride
Potassium Bifluoride
Potassium Polyacid Fluoride "50"
Sodium Bifluoride

6 Alkali Fluoborates

Ammonium Fluoborate
Potassium Fluoborate
Sodium Fluoborate

7 Metal Fluoborate Solutions

Cadmium Fluoborate
Chromium Fluoborate
Cobalt Fluoborate
Copper Fluoborate
Ferrous Fluoborate
Indium Fluoborate
Lead Fluoborate
Manganese Fluoborate
Mercuric Fluoborate
Nickel Fluoborate
Silver Fluoborate
Stannous (Tin) Fluoborate
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Fluoboric Acid
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of the industry's enviable wartime supply record, stand high among the things that have contributed to the present increasingly popular acceptance of petroleum. All of these are seemingly exerting maximum influence at a time when the industry is still handicapped as a result of the war, and a lack of time, personnel and the equipment necessary to rebuild and expand.

The Compact Committee's 5,000,000 barrels daily crude oil production requirement indicated for the next nine months is on the Bureau of Mines' basis which means that it includes about 40,000 barrels daily of condensate which is transported in crude oil pipelines and therefore mixed with in. That requirement figure on a crude oil only basis therefore becomes about 4,960,000 barrels daily and compares with the API figure of 5,008,050 barrels daily for the week ended May 17, a new all-time high for any one week.

Table 4's summary shows that California needs no special comment. Even though 50,000 barrels daily of crude may be transferred direct to fuel oil and exports may continue at about 19,000 barrels daily (current and past average rates) present crude oil production levels cover estimated refinery requirements for the period.

In the entire area east of California crude oil available as refinery runs total 4,296,650 barrels daily. Allowances were also made for transfers, imports and exports of crude. That figure compares with 4,260,000 barrels daily refinery runs required, indicating the area as a whole to be covered from a crude oil supply point of view on a normal demand basis. This is further supported by a reply to an inquiry addressed to Ernest O. Thompson, of the Railroad Commission of Texas, as follows:

"West Texas can easily produce an additional 165,000 barrels of crude per day and balance of the state an additional 65,000 barrels crude daily, making total conservative additional capacity of Texas crude Mer ability of 230,000 barrels daily over present rate of 2,183,500 barrels crude alone."

In Louisiana probably very few fields could stand sustained increased allowables without exceeding Mer's.

Going back to the table again, District 4 shows about 44,000 barrels daily crude oil supply over runs. Districts 1 and 3 combined (in which for the purpose of compiling this table the southeastern portion of New Mexico has been included), have another 435,000 barrels daily, or a total of about 430,000 barrels daily over required runs in these three areas. District 2 had net crude available during the week of May 17 from its own production of 898,000 barrels daily as against forward runs in the area of 1,340,000. If all of this indicated overage above normal demand requirements of other areas could be moved to District 2, the latter's availability would be 1,378,000 barrels daily, more than enough to cover its refinery requirements, but can these current overages all be moved into District 2 in present facilities? Of course the answer is no!

Before carrying this thought further, I should like to present a few pertinent figures.

During the year ended March 31, 1947 the district's refineries were operated at a daily rate of 1,232,000 barrels.

Crude oil stocks decreased from
82,320,000 bbl. on March 31, 1946
to 69,025,000 bbl. on March 31, 1947
or 13,295,000 bbl.—30,000 daily.

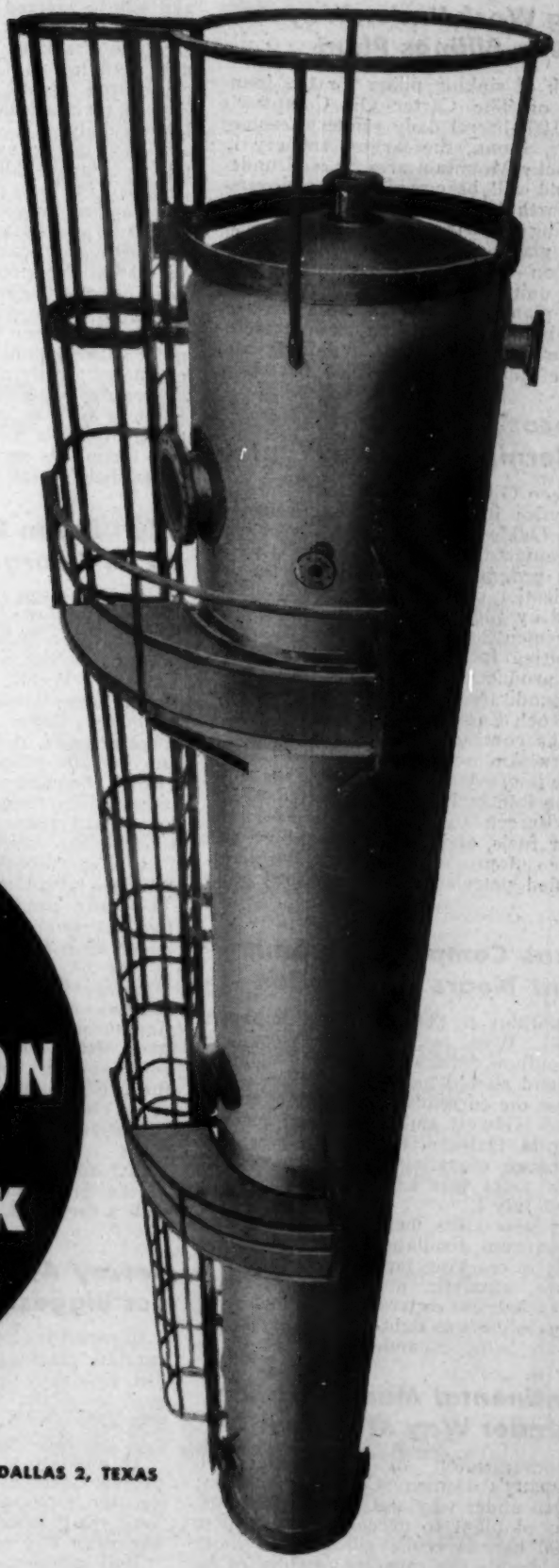
Stocks of principal refined products were
46,783,000 bbl. on March 31, 1946
and 42,781,000 bbl. on March 31, 1947
down 4,002,000 bbl.—11,000 daily
and those who operated in that area last winter will have an opinion as to whether these product stocks were high or low.

During the year referred to, all crude oil and product lines and other transportation into the district were being operated at capacity and I think daily crude capacity is about 330,000 barrels during any reasonable time period. Crude production in the area was at a maximum—940,000 barrels per day.

New Pipe Line Projects

If forward runs are 1,340,000 barrels daily, and if a rate of 1,232,000 caused crude withdrawals of 30,000 barrels daily, and 11,000 barrels daily of principal products during the year ended March 31, 1947, about 150,000 barrels daily more of crude or products are required in the area to arrest the downward trend of crude stocks. If that additional amount were to begin to move into the area immediately and be run to refineries normal seasonal rates of accumulation of products would take place but more is necessary if the depleted levels of working stocks on March 31, 1947 and worse, are not again to be experienced. If the indicated additional amount of crude and products are not moved into the area, and the only way they could be moved now is by tank car and barge, seasonal buildup will be lacking, and the consequent difficulties experienced. New pipe line projects to bring more crude into the area have been announced notable among which are the proposed 150,000 barrels daily 22-inch from Midland; the 20-inch from Corsicana to Patoka, Ill., and the looping of an existing line. Whether these can be completed and operated in time to be of help next winter remains to be seen, but they will have to be if the district is to obtain the crude it needs.

On the East Coast a serious situation has threatened to arise as a result of impending developments in the tanker transportation situation. Before the war there was always a so-called "free" tanker market in which tankers could be charted from independent ship owners, both foreign and domestic, for marginal requirements involving a voyage or two, or for a relatively short period. Since the war the so-called "free" tankers are very limited in proportion to the total requirements, mainly as a result of war losses in foreign flag tonnage, and much of the independent tonnage is taken up on long-time contracts, leaving very few available for spot chartering. Currently a world-wide shortage of tonnage has been relieved by government-owned ships being made available by the Maritime Commission under a general agency agreement. This arrangement was due to expire June 30, 1947 when the authority under which the Maritime Commission now operates expires. If the general agency agreement is eliminated without the creation of anything to take its place, worldwide availability of tanker tonnage would be reduced by approximately 25 percent, and although this would primarily affect foreign markets it will unquestionably have its repercussions on the United States Eastern Seaboard.



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Refinery Construction In Progress

Piling Work Under Way on Carter's Billings Plant

Work of sinking piling for the foundation of The Carter Oil Company's new 20,000-barrel daily refinery, east of Billings, Mont., the largest refinery in the Rocky Mountain area, is well under way and will be completed by November. Earth has already been moved in preparing the 344-acre site.

The plant, scheduled to be ready for operation late in 1948, will include a crude unit, a catalytic cracking unit, power plant, laboratory, shop and warehouse buildings, tank car loading facilities, process equipment buildings and storage capacity of 1,600,000 barrels.

Bareco Oil Company Modernizes Wichita Plant

Bareco Oil Company will expand and modernize its Wichita, Kan., refinery, V. R. Oakley, vice president in charge of manufacturing, has announced.

The program includes a catalytic desulfurization-catalytic reforming unit, licensed by Phillips Petroleum Company, replacement and modernization of steam generating facilities, and additional refined products storage facilities.

Expenditures will approximate $500,000. Koch Engineering Company, Wichita, has contracted for engineering and construction work for the Perco Unit.

The improvements, scheduled for completion late in 1947, are expected to enable Bareco to produce higher-octane motor fuels, and facilitate handling and storage of products including gasolines, liquefied petroleum gas and lubricating oils.

Texas Company Wyoming Plant Nears Completion

Additions to The Texas Company's Casper, Wyo., refinery, involving several million dollars, are nearing completion and should help, in some measure, to ease the current tight supply situation in the Midwest and Northwest, according to M. Halpern, Texaco vice president in charge of refining. Construction of major units was expected to be completed July 1.

Six new units include crude topping and vacuum distillation equipment, fluid catalytic cracking facilities, naphtha reformer, catalytic polymerization unit, and asphalt converters. In addition, present gasoline and light-oil treating facilities are being expanded.

Continental Modernization Is Under Way at Denver

Modernization of Continental Oil Company's Denver, Colorado, refinery, is well under way and calls for enlargement of plant to process from 8000 to 10,000 barrels crude oil daily or more than double the capacity established by the 1938 enlargement program.

The new crude topping unit equipment has been moved from one of Continental's refineries, recently shut down, and will be erected adjacent to the thermal cracking unit. A new thermofor catalytic cracking unit, the first such unit installed in Colorado, will be incorporated in the design, and it will have a reactor charge capacity of 6600 barrels daily.

A new gas recovery and stabilization unit is being installed, this section being designed for high recovery of propylene and heavier hydrocarbon fractions. The propanes and butanes so recovered will be further processed through a Universal Oil Products Company type catalytic polymerization unit.

Design of the crude topping and thermal cracking unit and of battery equipment is being done by Continental's own engineers, while the remainder of the processing equipment and erection of plant is in the hands of the Lummus Company, New York. Construction work will begin this summer with completion scheduled for fall, 1948.

Ethyl Baton Rouge Plant To Be Enlarged

A $20 million construction program for expanding its manufacturing facilities has been announced by Ethyl Corporation, which according to President Earle W. Webb, will provide for additional manufacturing capacity at the company's Baton Rouge, La., plant, now the largest of its kind in the world. Occupying 200 acres, the plant is an integrated chemical plant producing all the intermediate chemicals used in the tetraethyl lead manufacturing process and two of the three chief ingredients in "Ethyl" antiknock compound, which are tetraethyl lead and ethylene dichloride. The third important ingredient of the finished product is ethylene dibromide which is produced at Freeport, Texas, by the Ethyl-Dow Chemical Company.

New construction will include a substantial addition to tetraethyl lead facilities, sufficient ethylene dichloride capacity to match peak production needs, and corresponding increases in capacity for the production of sodium, chlorine, and ethyl chloride.

Ethyl Corporation has also announced plans to construct terminal storage plants on the East and West coasts and in the Mid-Continent area, and to install a drumming plant at Baton Rouge.

Jersey Awards Contract For Biggest Catalytic Unit

Contract for its new 41,000-barrel-daily catalytic cracking unit, a part of Standard Oil Company of New Jersey's expansion program for the Bayway plant near Linden, N. J., was let in June to C. F. Braun Company, Alhambra, Calif.

In addition to the new fluid unit, the project includes a 49,000-barrel-daily vacuum pipe still, a 260,000-pound-per-hour steam boiler, a 7500-kilowatt turbo-generator and auxiliary facilities.

Full completion will require two years although the catalytic unit, the largest ever to be designed, should be finished within 12 months after work actually is started.

Ohio Oil Company Plans $15 Million Expansion

The Ohio Oil Company has announced that it will build three major units at its Robinson, Ill., plant to be completed late in 1948 as follows:

Vacuum distillation pipe-still capable of processing 27,500 barrels of crude oil daily, boosting the 15,000-barrel current rate by 60 percent; a fluid catalytic cracking unit with daily capacity of 12,400 barrels charging stock; and a polymerization unit to handle light gases from the cracking unit and produce high-octane polymer for blending.

Auxiliary facilities include two new boilers to bring capacity up to 300,000 pounds of steam an hour; two steam turbo generators, each of 5000 kva capacity; and substantial storage capacity for both crude and products.

A tetraethyl lead blending plant with rated capacity of 2000 gallons a minute will be built.

Total cost will be about $15 million, C. Z. Hardwick, vice president in charge of refining and marketing, said.

Contracts for Rebuilding Are Awarded by Monsanto

Contracts for the reconstruction of part of the Monsanto Chemical Company plant which was destroyed in the Texas City disaster April 16, have been let to the W. S. Bellows Company of Houston, and the Leonard Construction Company of Chicago, Illinois, it was announced today.

The Bellows company will do all of the building work, while the Leonard company will install chemical process equipment and do piping and mechanical work. J. R. Mares, general manager of Monsanto's Texas Division, estimated that the building contract would exceed $1 million, while mechanical installations, etc., would approximate $5,000,000.

Rebuilding of the remainder of the plant will be started when this work is substantially completed and the plant is again in operation.

Salvage operations are being handled by Lipsett, Inc., of New York.

Mid-Continent to Expand

Mid-Continent Petroleum Corporation will increase the throughput of its Tulsa plant to 45,000 barrels daily along with addition of modern processes in a program that calls for expenditure of $8,500,000. The M. W. Kellogg Company will be general contractor.

A Fluid type catalytic cracking unit of 17,400 barrels daily capacity, a two stage vacuum crude distillation unit, a polymerization unit and the necessary additions to utilities are major items in the construction program.

Canadian Project

Imperial Oil, Ltd., is contemplating erecting of a refinery at Edmonton, 16 miles from Imperial's new Leduc field. The project would depend upon development of sufficient reserves at Leduc to justify the expenditure.

Texas City Explosion

Plants Are Absolved from Blame

Effect of the ammonium nitrate explosion at Texas City, April 16, 1947 upon refining and petro-chemical plants as well as the role of these installations in the fires, which followed the explosion are a part of the report made for John G. Simmonds & Company, Inc., oil insurance underwriters of New York, by George Armistead, Jr., Washington, D. C. R. N. Blaize and J. L. Armstrong, Houston engineers, were associated in the investigation, which has been compiled into a report of 55 pages, plus illustrations and an appendix.

Copies of the report in limited numbers are available through John G. Simmonds & Company, Inc., New York.

Below are the principal conclusions offered by the investigators as a part of this report:

"1) The ship explosions appear, beyond reasonable doubt to have occurred as the result of detonation of ammonium nitrate by a presently imperfectly understood mechanism, caused by fire.

"2) These ship explosions were the prime cause of the loss of life and destruction of property, either through the direct and instantaneous effects of their blasts or by fires and other destruction which they initiated and which in some cases spread substantially before being checked.

"3) There is no credible evidence that the fires and other destruction in oil and chemical plants had any effects which extended outside the respective areas where such destruction had occurred. Specifically, there has been no indication found of explosions in those installations which threw destructive projectiles into other areas, the release of inflammable vapors which caused destruction elsewhere, or the like. No fatalities are known to have resulted from refinery or chemical plant fires in ways which were wholly unassociated with the direct effects of the ship explosions.

"4) The oil and chemical facilities, including storage tanks, stood up remarkedly well under the punishment of the terrific ship blasts. Only approximately 22 percent of the petroleum and other hydrocarbons stored within 1⅓ miles of the blast were lost by fire and only about 13 percent of the storage capacity on the basis of barrels or number of tanks experienced fire, although much damage was suffered. Damage to process facilities in the main resulted directly from the ship explosions (concussions or missiles) or from the fact that the great loss of life and injury to personnel as well as destruction of fire fighting facilities left the equipment long unattended.

"5) It is manifestly impractical to build oil or chemical processing and storage facilities or any other sizable industrial structures or buildings which will stand up against such terrific explosions as the detonation of 1000-2000 tons of ammonium nitrate within a few hundred feet. The remedy for preventing recurrence of such disasters must lie in the elimination of such explosions.

"6) The mechanism of the ammonium nitrate detonations at Texas City, and factors controlling the tendency of this material to detonate are not clearly understood. Until the properties and sensitiveness of ammonium nitrate and its various mixtures with other materials are clearly established beyond reasonable doubt, such materials should be marked, shipped and handled as substances which will explode when exposed to fire and/or other conditions not yet defined. Demonstrated properties of the material at the Texas City disaster should remove any reluctance on the part of official agencies, shippers or others concerned to take such action, since cost cannot be counted in avoiding consequences such as those of the Texas City disaster.

"7) The Texas City explosions in relation to past history of ammonium nitrate accidents indicate the necessity of the adoption of a conservative policy toward such materials when inconsistencies are evident in the known history. The public interest would seem to raise the question also as to whether the established agencies for classifying materials in this regard adhere to a properly conservative policy for other materials which may be suspected as explosives or otherwise dangerous."

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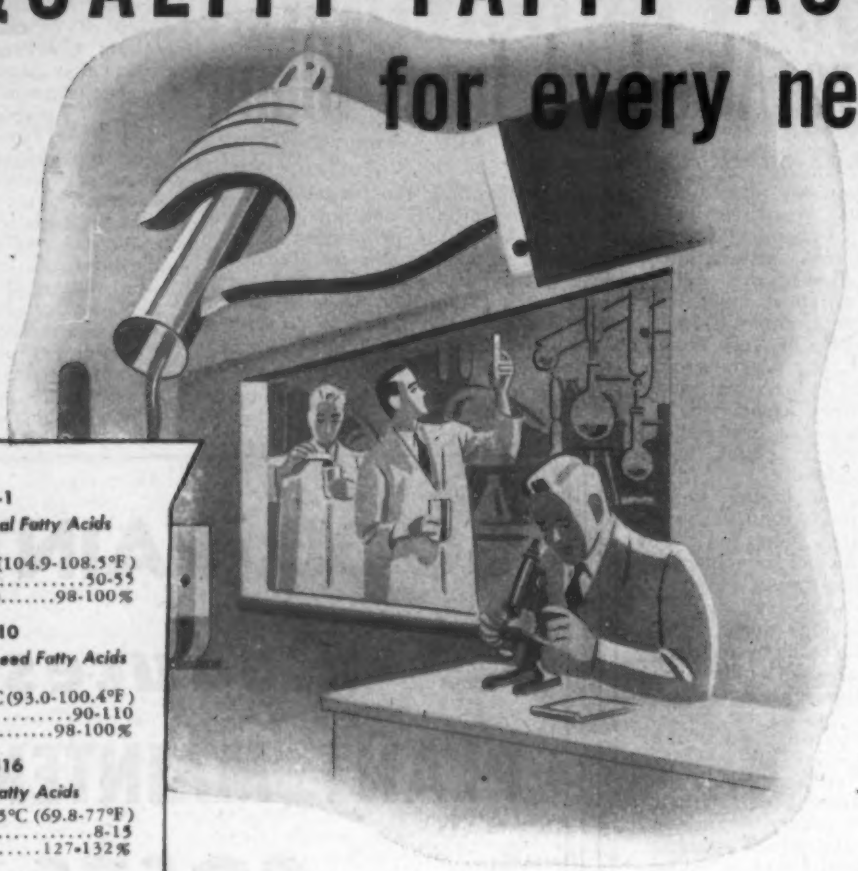

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Distilled Animal Fatty Acids
Titre
40.5-42.5°C (104.9-108.5°F)
Iodine Value.....50-55
F.F.A. (as oleic).....98-100%

F-10
Distilled Cottonseed Fatty Acids
Titre
34.0-38.0°C (93.0-100.4°F)
Iodine Value.....90-110
F.F.A. (as oleic).....98-100%

F-516
Coconut Fatty Acids
Titre.....21-25°C (69.8-77°F)
Iodine Value.....8-15
F F A (as oleic).....127-132%

Hyfac 54
Hydrogenated Fish Oil Fatty Acids
Titre..54-56°C (129 2-132.8°F)
Iodine Value.....2-3
F.F.A. (as oleic).....96.5-99%

S-512
Special Solid Fatty Acids
Titre
...57.2-60°C (135.0-140.0°F)
Iodine Value.....2-5
F.F.A. (as oleic).....100-103%

O-18
Elaine (red oil)
Titre.....8-11°C
Iodine Value.....90-93
F.F.A. (as oleic).....97-99%

S-25
Standard Stearic Acids
Titre
129.0-130.0°F (53.9-54.4°C)
Iodine Value (max).....7.0
F.F.A. (as oleic).....102-105%

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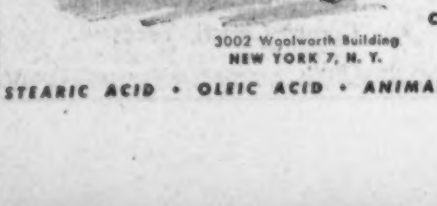

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Natural Gasoline Group Re-elects Bacon Chairman of Corrosion Research Project

T. S. Bacon, chief engineer, Lone Star Producing Company, Dallas, has been re-elected chairman of the Corrosion Research Project Committee of the Natural Gasoline Association of America. Vice chairman is M. E. Holmberg, Phillips Petroleum Company, Bartlesville. The organization meeting in Dallas also provided for the following sub-groups:

Steering Committee, T. S. Bacon, chairman; M. E. Holmberg, vice chairman; C. F. Bedford, Stanolind Oil & Gas Company; Houston; J. M. Dillon, Jr., Shell Oil Company, Houston; and W. H. Justice, Tide Water Associated Oil Company, Houston. Chemical Advisory Committee, E. C. Greco, United Gas Pipe Line Company, Shreveport, chairman; Dr. W. A. Bruce, The Carter Oil Company, Tulsa; C. K. Eilerts, U. S. Bureau of Mines, Bartlesville; Paul Menaul, Stanolind Oil and Gas Company, Tulsa; and D. A. Shock, University of Texas, Austin. Economics Committee, W. H. Stewart, Sun Oil Company, Beaumont, chairman; F. A. Hunter, J. S. Abercrombie, Houston; and T. S. Zajac, Shell Oil Company, Inc., Houston. The latter committee is a newly formed group to which has been assigned to study of the relative cost of corrosion inhibition by chemical injection in wells as compared with the use of alloy fittings and pipe.

Formed three years ago for the purpose of determining the causes and possible cures for the destructive corrosion encountered in high pressure gas-condensate wells, the committee has made constructive progress with the many problems involved. The project is a cooperative one to which 25 interested producing companies have contributed more than $60,000 to forward the research studies of the committee and the agencies it has retained.

In summing up the progress to date and committee plans for the future, Chairman Bacon stated the vast amount of factual data accumulated has confirmed the effectiveness of chemical treatments of wells. "Inhibitors and alkalis are being used in many producing fields and the practical benefits obtained from their use have been demonstrated beyond any shadow of doubt. Specific reports have been obtained on 52 different inhibitors and alkalis, though no chemical treatment has been found that is applicable to all condensate wells. The committee will expand its study of inhibitors, particularly their specific action in the absence of oxygen and at elevated temperatures. Under committee direction, Dr. H. L. Lochte, University of Texas, is attempting to determine the chemical composition of natural inhibitors believed to be present in non-corrosive wells so that they may be used in the treatment of corrosive wells. At the same institution Dr. Norman Hackerman is studying the action of known inhibitors and is attempting to devise more satisfactory methods for their evaluation. He will be joined in this work by Mr. D. A. Shock who has served as full-time field correlator for the committee during the past year. In addition to this work, Mr. Shock will make laboratory studies of two repeating types of corrosive well behavior to determine the most effective means of neutralization. New types of protective coatings for tubing are being studied and experiments are being conducted with many different types of alloys."

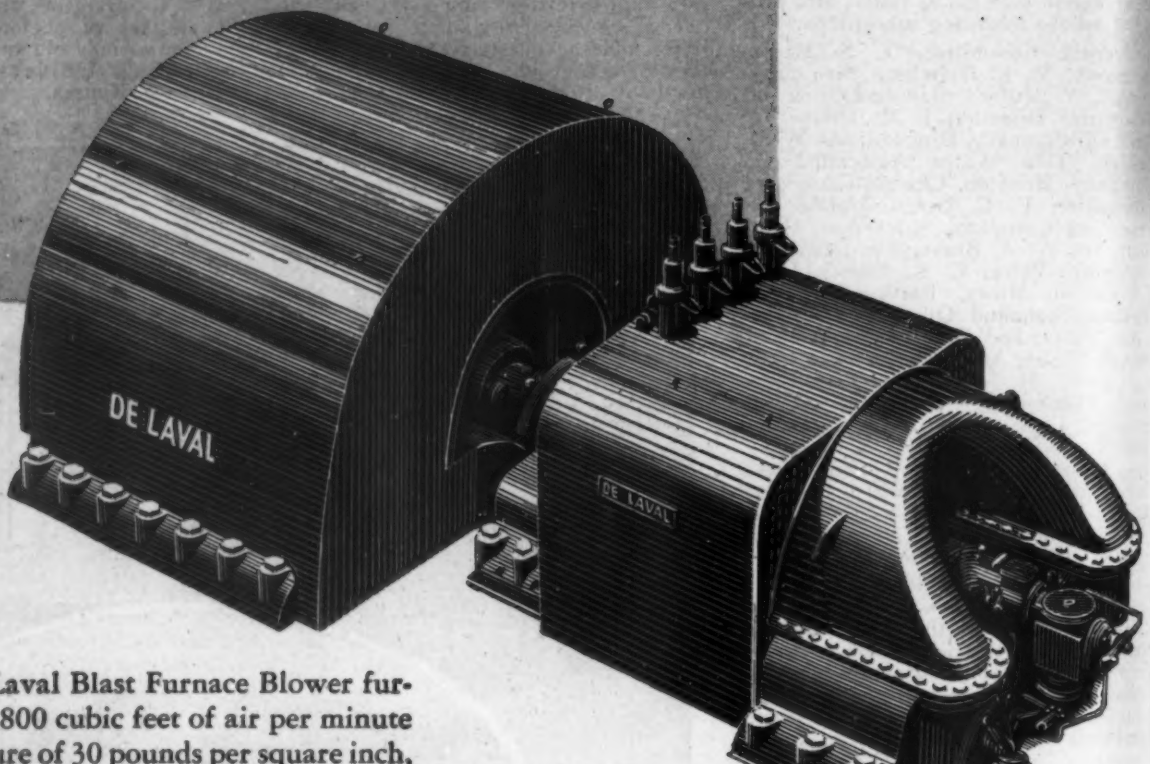
It was stated plans have been completed for spreading the research project over a five-year period, on a year to year basis, and the quarterly two-day meetings of the group to discuss individual company methods and report on field activities will be continued. The next meeting is scheduled for early September in Corpus Christi.

Industrial Research Grants

The University of Wichita Foundation for Industrial Research is offering two graduate fellowships, leading to the master's degree at the University of Wichita for the academic year 1947-48. Each carries a stipend of $1000 for the degree, plus tuition and fees. One is in chemistry and will permit full time work and the obtaining of the degree in one year if requirements are met.

Graduates of accredited colleges or universities may obtain details from Dr. Hugo Wall, University of Wichita, Wichita 6, Kansas.

AIR
BY THE TON



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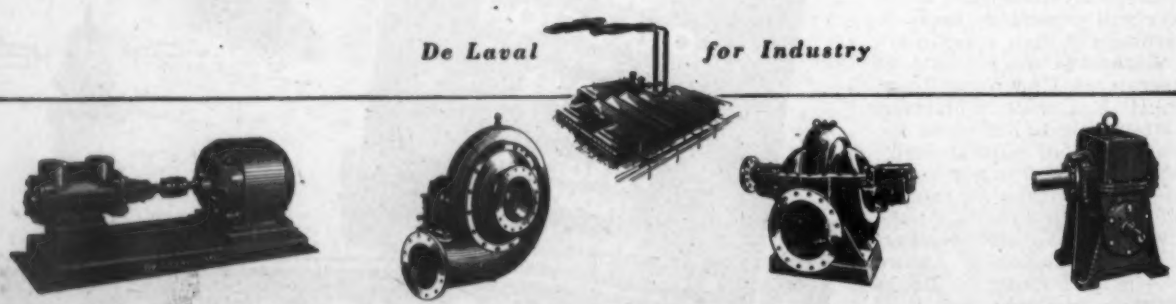


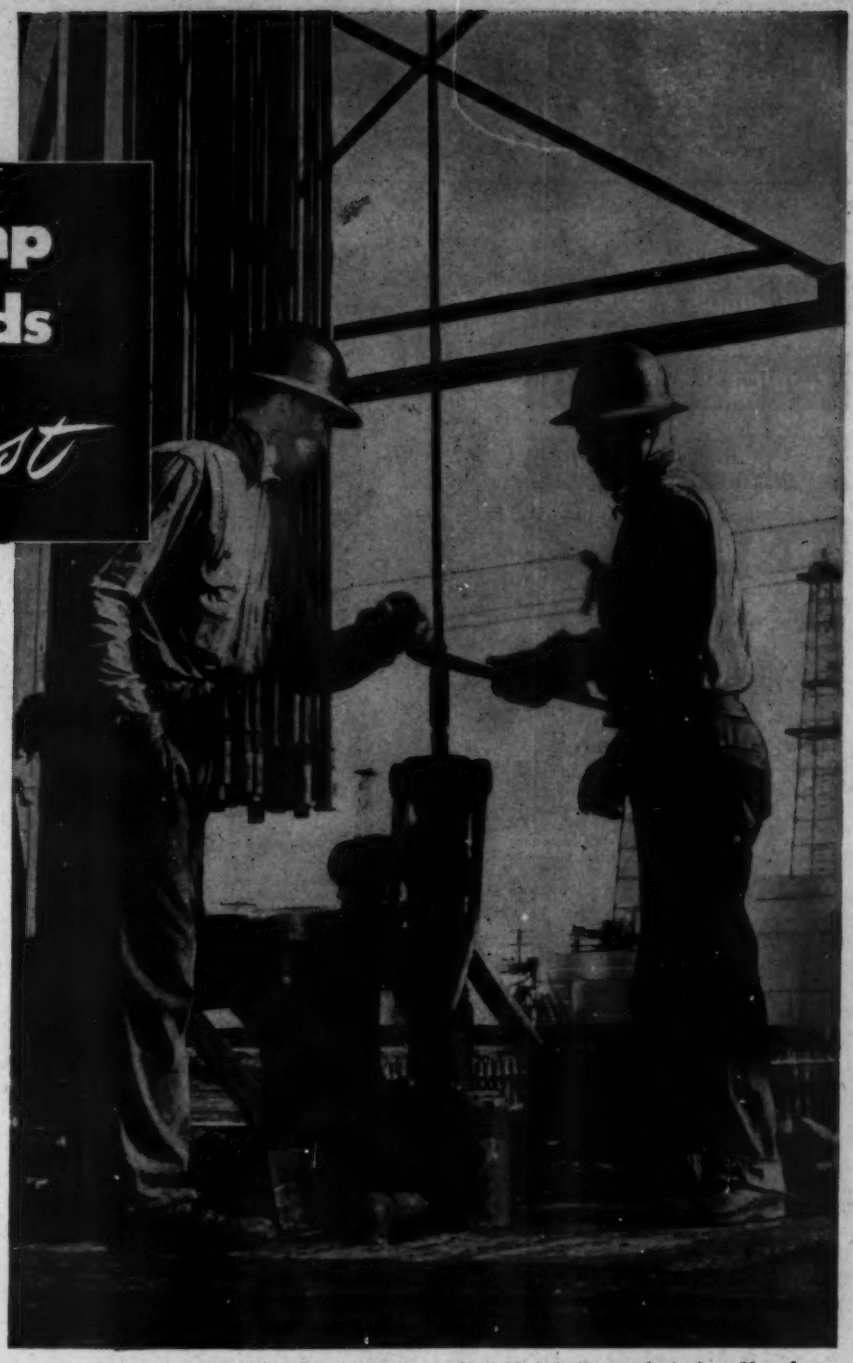
C-1

DE LAVAL STEAM TURBINE COMPANY · TRENTON 2, N. J.

TURBINES · HELICAL GEARS · WORM GEAR SPEED REDUCERS · CENTRIFUGAL PUMPS · CENTRIFUGAL BLOWERS AND COMPRESSORS · IMO OIL PUMPS

How to Pump Heavy Loads

... at low cost



It is well established that sucker rods made of Nickel-molybdenum steels of the 4600 and 4800 series resist heavy stresses and have given the best and most economical performance to date in pumping oil wells.

When hydrogen sulphide and salt water are present in the wells, this Nickel-molybdenum steel with its high corrosion-fatigue strength is particularly useful in extending the life of the sucker rods, thereby avoiding excessive replacements.

Specify 4600 Nickel-molybdenum steel sucker rods and convince yourself of their superiority.

Unloading Axelson sucker rods of Nickel alloy steel. Axelson Manufacturing Company, a firm that specializes in producing sucker rods and accessories only, pioneered use of Nickel-molybdenum steels in this field. Now one of the largest producers, Axelson's monthly capacity is 1,500,000 feet of rods, normalized and tempered throughout their entire length.

EMBLEM OF INCO SERVICE

TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes and other alloys containing Nickel. This information and data are yours for the asking. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

THERE is a wealth of practical, up-to-date factual information about expansion joints and flexible connectors packed into this *new* 60-page catalog compiled by the technical staff of Zallea Brothers & Johnson.

For instance, twenty double-pages offer specific, usable data on the many types of Zallea expansion joints. There's a full description of the manufacturing process for every expansion joint that includes welding and forming, annealing, pickling and passivating.

In addition you'll find detailed discussions on how to select the proper expansion joint for each specific application and the advantages of each, *plus* many charts and diagrams. Also, it's profusely illustrated with photographs of actual applications.

Never before has such a complete, comprehensive catalog been published on expansion joints and flexible connectors *exclusively.* Catalog 47 is *FREE* . . . a request on your company letterhead will bring it to you. Use it as a guide or as a permanent reference source. And when unusual conditions confront you, ask for the assistance of our technical specialists. *Zallea Brothers & Johnson, 890 Locust Street, Wilmington 99, Del.*

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EXPANSION JOINTS

WORLD'S LARGEST MANUFACTURERS OF EXPANSION JOINTS EXCLUSIVELY

Bibliography of Coal Investigation Ready

The United States Bureau of Mines, through the Superintendent of Documents, Government Printing Office, Washington, price 15 cents, now has available a bibliography of research in coal from 1940 to 1945.

The investigations on coal and its products have been described in detail in previously printed or mimeographed publications issued by the Government Printing Office or the Bureau of Mines and in articles by staff members published in periodicals, books, and journals distributed by the technical press.

Technical Paper 698 classifies these publications into 19 divisions according to subject matter. These divisions are general publications; methods of sampling, analyzing, and testing; occurrence, origin, microstructure, classification, proximate and ultimate analyses, calorific values, and fusing temperatures of ash; physical and chemical properties of coal; gases and dusts; mining; mine water and correction; preparation; sizing; cleaning; cleaning and briquetting, including testing methods; storage, spontaneous heating, and oxidation of coal; carbonization, including testing methods; complete gasification; water-gas, producers-gas, and mixed-gas production; hydrogenation and synthetic products; coke; gas; tar, light oils, and other byproducts; combustion; smoke abatement; economics and statistics; and motion-picture films.

The bibliography with indices of subjects and authors was compiled by Dr. A. C. Fieldner, Chief of the Fuels and Explosives Branch, Bureau of Mines; P. L. Fisher, former coal technologist, and Marjorie B. Pollock, research assistant, Fuels and Explosives Branch.

Petroleum Publications

More than 250 Bureau of Mines publications and special articles dealing with the chemistry and refining of petroleum and oil shale are enumerated in a list of publications now available.

Included in the bibliography are titles of previously published reports on Bureau petroleum and oil-shale research during the past 35 years. Although some of the complete publications now are out of print, these reports may be consulted at depository libraries.

The list also contains titles of reports based on cooperative work with the state of Oklahoma at the Petroleum Experiment Station at Bartlesville, Okla., and with the University of Wyoming at the Petroleum and Oil-Shale Experiment Station at Laramie, Wyo.

This "Selected List of Bureau of Mines Publications Dealing with the Chemistry and Refining of Petroleum and Oil Shale," may be obtained by writing to the Bureau of Mines, Department of the Interior, Washington 25, D. C.

Honorary Degree to Brown

Technical knowledge has become so important that today scientists rank beside statesmen in shaping world affairs, Richard P. Brown, chairman of the board of Brown Instrument Company, told June graduates of Drexel Institute of Technology at commencement exercises during which he was awarded the honorary degree of doctor of engineering.

THE MONTH IN THE INDUSTRY

Revised Basis for Middle East Oil Deal Announced

A revised for the agreement by major partners of Iraq Petroleum Company, one acceptable to French participants has been reached by participants. If concluded as drawn the agreement would replace the agreement of 1928 and thus remove the objections instituted by French partners to the action to prevent Standard Oil Company (New Jersey) and Socony-Vacuum Oil Company from acquiring an interest in Arabian American Oil Company.

Pending further action on the agreement the offer of the two companies to buy stock in Arabian American is still pending.

Recently Standard Oil Company (New Jersey) announced that it has no present plans for importing crude oil from the Middle East into the United States. Its efforts to buy crude oil in the Persian Gulf area have been based on the necessity of taking care of European needs.

Alexander Fraser Named President of Shell Union

Election of Alexander Fraser, president of Shell Oil Company, as president and a director of Shell Union Oil Corporation, has been announced by R. G. A. Van der Woude, retiring head of Shell Union. H. S. M. Burns, senior vice president, will succeed Fraser as head of Shell Oil.

Fraser became associated with the Shell organization at the close of World War I. He held various executive positions and in 1935 became president of Shell Petroleum Corporation. In 1939, when Shell's operations in the United States were combined in a single operating company, Fraser became head of Shell Oil Company.

Van der Woude recently completed 40 years of service with the Shell group. He joined Shell Petroleum in 1922 as vice president and became its president in 1931. He was elected head of Shell Union in 1933.

Burns has been associated with Shell for more than 20 years, having joined the company in California as a geophysicist in the exploration department.

Meetings

July

10—National Petroleum Council, Washington, D. C.

August

11-12—Interstate Oil Compact Commission, Great Falls, Montana.

25-27—Appalachian Gas Measurement Short Course, West Virginia University School of Mines, Morgantown.

September

8-12—Instrument Society of America, conference and exhibit, Stevens Hotel, Chicago.

15-17—National Butane-Propane Association, Jefferson Hotel, St. Louis.

15-19—American Chemical Society, Division of Petroleum Chemistry, annual meeting, Waldorf-Astoria, New York.

17-19—National Petroleum Association, Hotel Traymore, Atlantic City, New Jersey.

23-25—Pacific Coast Gas Association, Coronado Hotel, San Diego.

29 to Oct. 3—American Gas Association, San Francisco.

October

6- 8—American Society of Mechanical Engineers, Petroleum Mechanical Engineering conference, Rice Hotel, Houston.

16-18—National Lubricating Grease Institute, annual meeting, Edgewater Beach Hotel, Chicago.

21-25—Pacific Chemical Exposition, San Francisco.

November

6- 7—Society of Automotive Engineers, fuels and lubricants meeting, Hotel Mayo, Tulsa.

10-13—American Petroleum Institute, Stevens Hotel, Chicago.

ALEXANDER FRASER

H. M. S. BURNS

Pennsylvania Group Elects Officials

Officials of the Pennsylvania Grade Crude Oil Association, elected at the annual meeting, include: D. T. Ring of Preston Oil Company, Columbus, Ohio, president; B. T. Haskins of Ebenezer Oil Company, Wellsville, N. Y., first vice president; George J. Hanks, president of South Penn Oil Company, Bradford, Pa., second vice president; Fayette B. Dow of Washington, D. C., vice president and general counsel; Samuel Messer of Quaker State Oil Refining Corporation, Oil City, treasurer; assistant treasurers—W. R. Reitz, of Quaker State Oil Refining Corporation, and C. L. Suhr of the Pennzoil Company, both of Oil City; and W. C. Wenzel of Oil City, executive manager.

New directors are as follows: D. S. Keenan, Carnegie Natural Gas Company, Pittsburgh; N. V. V. Munson, Franchot Estate, Olean, N. Y.; W. R. Reitz, Quaker State Oil Refining Corporation, Oil City; A. J. Saxe and John E. Selden, South Penn Oil Company, Bradford, and W. S. Zehrung, Pennzoil Company, Oil City.

Ibach Is Superintendent Of Alamo's Sweeny Plant

G. A. Ibach, formerly superintendent of Phillips Petroleum Company's plant at Okmulgee, Okla., will be superintendent of the Sweeny, Texas, (Old Ocean), plant the purchase of which by Almo Refining Company from War Assets Administration recently was closed. Alamo is owned 80 percent by Phillips. A. B. Leonard of Phillips' Kansas City refinery, will be assistant superintendent at Sweeny.

Workmen have started rehabilitation of the plant which is expected to be in full operation within a few weeks. Equipment will be changed from its original aviation-fuel set-up to the production of gasoline, kerosine, diesel fuels, industrial oils and other products. The plant has a rated capacity of 24,000 barrels of crude oil daily, comprises 508 acres of land, and 30 buildings containing 73,000 square feet of space. Purchase price was $13,100,000.

Rehabilitation of Foreign Oil Plants Declared Needed

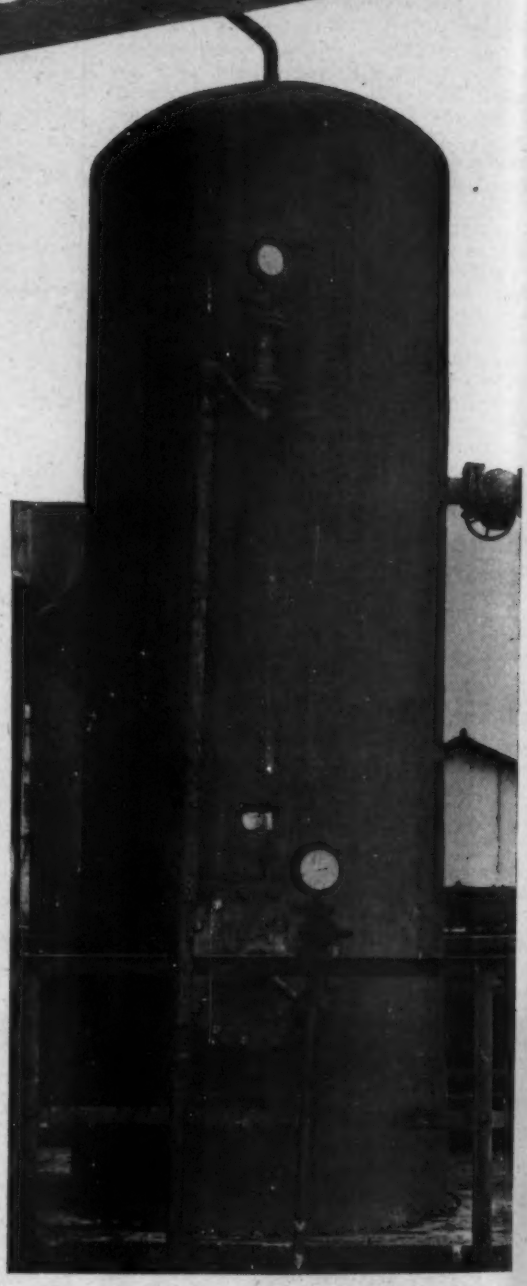
The answer to the tight oil supply situation is expansion of plant capacity of American companies operating abroad. This is the opinion of the materials committee of the National Petroleum Council as set forth in a mid-June report.

The committee asked the government to clear the atmosphere so that needed materials could be had in order to meet the unprecedented demand for petroleum products. Existing plants which were damaged during the war must be rehabilitated and expansion effected before world-wide demand and supply can be brought into balance, the report declared. Such a development would relieve the heavily over-burdened domestic industry, it was said.

Critical materials should not be permitted to move to foreign areas until

STAINLESS to lick corrosion

CLAD to lick cost



This caustic tower was fabricated of a Lukens Clad Steel to resist corrosion. It was fabricated by Southwest Welding and Manufacturing Co., Alhambra, Calif., and is 54" O.D. by 15'0" high.

You win both ways—gain protection and economy—when your petroleum refining equipment is made of Lukens Stainless-*Clad* Steels.

Our stainless cladding is as durable and highly resistant to corrosive conditions as solid stainless itself. But savings in material costs are as much as 50 per cent!

Any specification you want. Most of our customers buy Stainless-Clad Steels with cladding of 10 or 20 per cent of total plate thickness. But other percentages from 5 to 50 are equally available. The stainless may be of any standard type. It is permanently bonded in a *uniform thickness* to any required quality of carbon or low alloy steel, for high or low temperature service.

. . . and wide, for lowest-cost fabrication. On many jobs, you can save time and cut fabrication costs as much as 7 cents per pound of plate weight by using a single wide plate instead of narrow widths. We make Stainless-Clad Steels in plates *up to 178" wide*, or from $\frac{3}{16}$" to over 3" thick. You can get heads in all styles and sizes to over 18' in diameter.

Further information on Lukens Stainless-Clad Steels is contained in Bulletin 338; on Lukens Nickel-Clad, Inconel-Clad and Monel-Clad Steels, in Bulletin 255. Please write for copies. Lukens Steel Company, 404 Lukens Building, Coatesville, Pennsylvania.

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Nickel-Clad Stainless-Clad
Inconel-Clad Monel-Clad
STEELS

SOLID METAL ADVANTAGES WITH CLAD-STEEL ECONOMY

THE MONTH . . .

after United States' basic needs for such items are met, the report went on.

Mounting demand at home means more wells, crude oil, refineries, tank cars, etc., and with 10 bottleneck materials still far short of needs, there is urgent reason for the government to apply effective labor legislation that will encourage productivity instead of strikes, it pointed out.

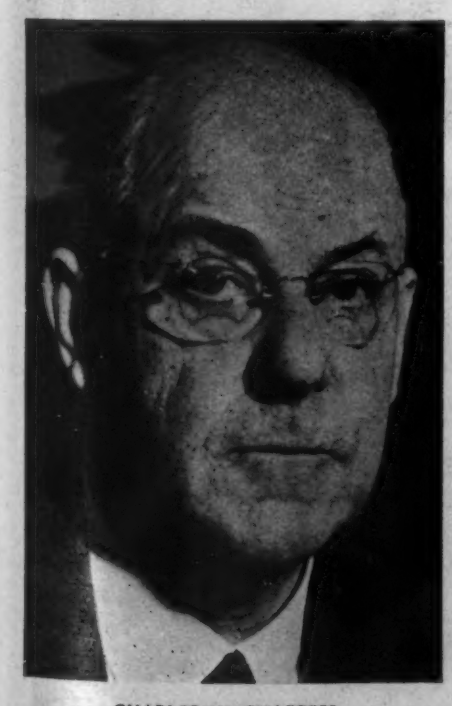
Shaeffer Retires as East Providence Plant Manager

Charles W. Shaeffer retired July 1 as manager of the East Providence plant of Socony-Vacuum Oil Company, where he had been since 1920. He has been succeeded by Henry A. Rickett, former superintendent of the plant who has been at the plant since 1915 and was assistant to Shaeffer for 15 years.

Shaeffer remained with the company until he was 68 years old, three years beyond retirement age, in order to assist wtih the winding up of affairs that accumulated during the war period. His first work was as office boy with the Devoe works of Standard Oil Company of New York at 26 Broadway, New York. After four years he went to the can factory on Long Island City as bookkeeper and in 1907 he became its superintendent. With the dissolution of the Standard Oil Company he became a member of the manufacturing committee of the company.

In 1913 he made an extensive tour of the Orient in order to study conditions of shipping and handling kerosine. While he was away two fires occurred at the Long Island City plant and he was called home to supervise rebuilding. He became superintendent of the Long Island plant in 1918 and two years later moved to East Providence.

In this post he also operated the first products pipe line in New England from the plant to Springfield and Worcester, Massachusetts.



CHARLES W. SHAEFFER

Republic Refining Names Thompson Vice President

D. C. Thompson has been elected vice president of Republic Oil Refining Company. He will be assistant to J. M. Gardiner, vice president in charge of sales.

Thompson joined the company in April, 1946, as a special representative. He was previously with The Atlantic Refining Company in Philadelphia for nearly 39 years. His headquarters will remain in Pittsburgh, the home office of Republic.

ACS Chapter Formed By Tulsa Chemists

A new chapter of the American Chemical Society has been formed in Tulsa, with Buell O'Connor as head of the group. Before organization of the Tulsa group, members of the only group of the national society in Oklahoma had been organized under the unchartered Oklahoma Section, with headquarters at Stillwater.

Other officers elected include: Dr. Paul H. Caldwell, vice chairman; Walter Duncan, secretary, and Harvy Phillips, treasurer.

Burton Logue and R. W. Provine have been chosen councilors to represent the local organization at the national conventions. Dr. Leslie Nunn and Dr. F. T. Gardner were appointed committee chairmen.

Russia Claims Gains

Russian reports reaching Washington say that gasoline production for the first quarter of 1947 was 50 percent in excess of the same period last year. No figures on which the comparison was based were given.

Roark Retires as Area Manager in Oklahoma

R. B. Roark, vice president of Shell Oil Company and manager of its Tulsa area, retired July 1, after 29 years with the company. He has been succeeded by W. A. Alexander, who was area manager in Houston previous to his transfer to the Oklahoma post.

Roark is a native of Oklahoma, who was educated in the public schools at Wagoner and at the University of Oklahoma. He joined the Shell organization in 1918 after graduation from the Norman school, serving as instrument man. Following duty in World War I, he returned to Shell as an assistant geologist and progressed through various positions to that of vice president in 1937.

Alexander is a native of Louisiana and was graduated from the state university at Baton Rouge in 1928.

Iranian Oil to Plant In Italy for Refining

Azienda Generale Italiana Petroli and Anglo-Iranian Oil Company have formed "Industria Rafinerie Olii Minerali per l'Industria del Petroleo in Italia." It will receive Middle East crude to the value of $8 million yearly which will be treated at the Porto Marghera, Venice, refinery, which will be enlarged to a capacity of 3 million barrels yearly.

Pan American Purchases Stone Oil Company Plant

Pan American Refining Corporation late in June announced that it had completed arrangements for purchase of the Stone Oil Company refinery at Texas City, Texas. The Stone plant is adjacent to the Pan American property there and has been operated by the purchaser on a lease basis for four years. The 20-odd acre Stone plant, consisting of a 6000-barrel per day continuous crude fractionator, several shell stills, specialty units, related tankage, etc., was heavily damaged during the Texas City disaster in April.

Frank J. Smith, head of Pan American's Chemicals Division, said that the Stone facilities will continue to be employed chiefly in production of specialty items. Damaged equipment will be repaired or replaced as soon as possible.

Second Instrumentation Short Course Announced

The second annual short course, "Instrumentation for the Process Industries," will be held under auspices of the engineering department of Texas Agricultural & Mechanical College, College Station, August 27, 28 and 29.

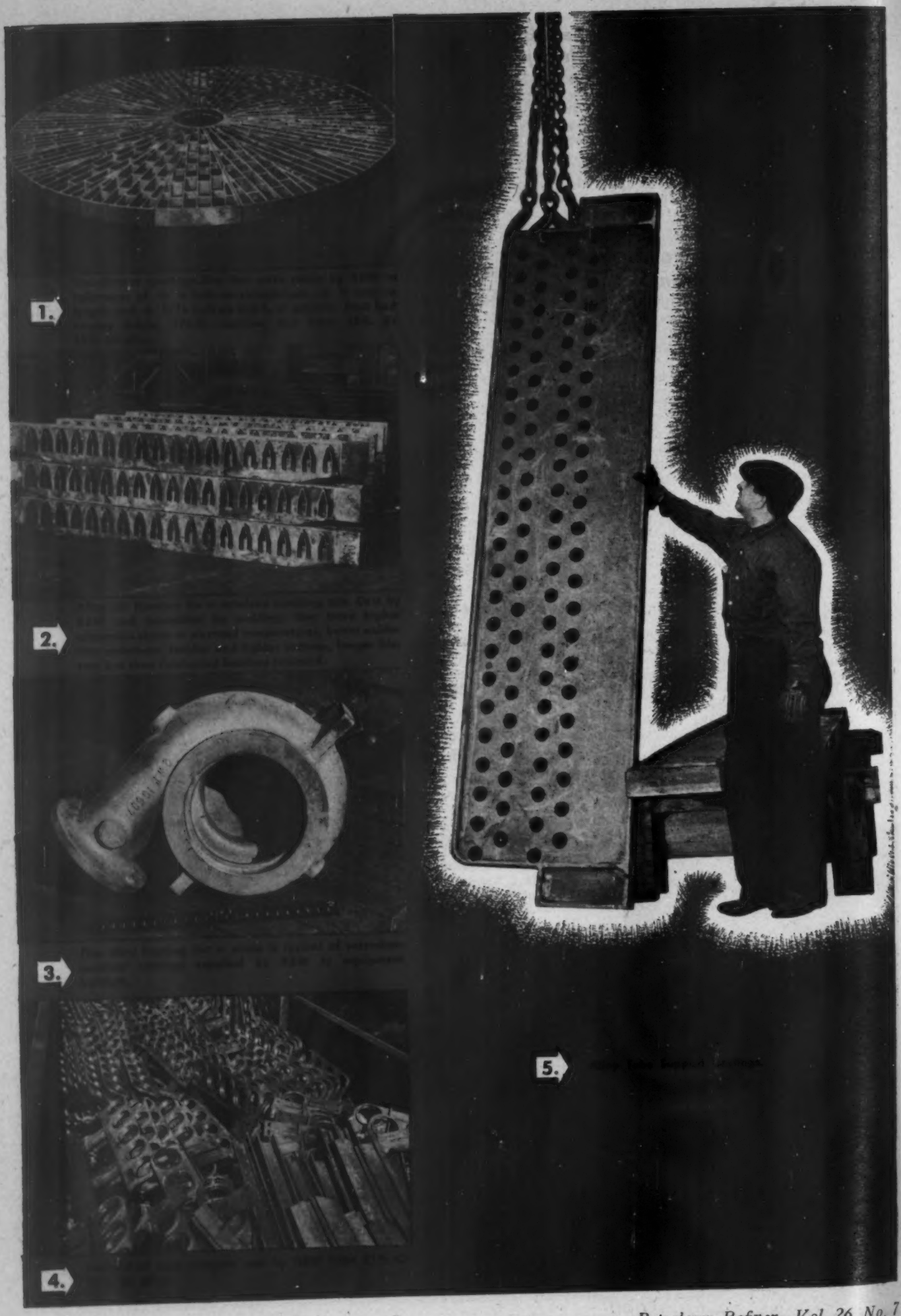
Last year the program drew attendance of more than 200, most of them from the operating personnel of indus-

Trends of Operations and Changes in Stocks

Figures on crude stocks are from Bureau of Mines weekly reports; all others from American Petroleum Institute weekly reports, which are estimates on Bureau of Mines basis.

(All figures in thousands of barrels—add 000)

Trends in Week Ended	Crude Oil			Gasoline		Gasoil and Distillate		Residual Fuel	
	Production Daily	Runs to Stills Daily	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End
1946:									
January 26	4,626	4,553	220,544	13,622	101,737	5,720	29,498	8,411	39,722
March 2	4,726	4,779	229,430	13,871	104,462	5,888	25,148	8,634	38,441
March 30	4,425	4,684	224,994	13,896	104,715	5,337	28,240	8,738	37,746
April 27	4,672	4,685	224,443	14,228	99,631	5,568	30,466	9,204	39,404
May 25	4,759	4,857	222,214	14,322	95,769	5,463	32,973	8,968	43,368
June 29	4,957	4,854	223,883	14,500	92,333	5,325	37,762	8,828	46,447
July 27	4,926	4,896	223,756	14,535	88,626	5,817	44,316	8,217	49,517
August 24	4,836	4,866	225,672	14,639	86,251	5,649	51,405	8,126	52,061
September 28	4,778	4,829	221,903	14,538	85,854	5,450	57,903	8,158	56,914
October 26	4,730	4,758	221,184	14,863	84,623	5,710	65,499	7,728	60,872
November 30	4,795	4,707	225,119	15,145	88,371	5,228	66,062	7,672	58,647
December 28	4,713	4,968	226,111	15,604	93,126	5,931	58,941	8,181	53,427
1947:									
January 25	4,672	4,820	221,655	14,624	99,801	5,630	50,357	8,224	48,558
February 22	4,786	4,860	224,580	14,668	103,904	5,929	40,739	8,532	44,919
March 29	4,865	4,843	225,720	14,396	107,576	5,969	32,737	8,668	43,364
April 26	4,930	4,725	234,051	14,213	103,860	5,435	32,286	8,186	42,668
May 31	5,024	5,000	239,370	14,709	95,576	5,732	36,132	8,910	45,224
June 28	5,109	5,093	.....	16,070	91,806	5,606	41,721	8,298	48,490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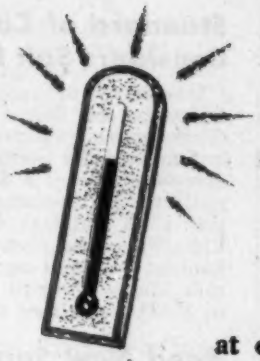
CAST to LAST

in high-temperature service



Vital to many different kinds of refinery equipment, B&W Alloy Castings are demonstrating outstanding ability to resist abrasion, corrosion and oxidation, and to retain great strength at elevated temperatures.

Operating in about every kind of tough service, they are helping to keep production up by reducing costly, time-consuming repairs and replacements. Their long-life characteristics have been proved over and over in service temperatures up to 2000 F, and under conditions requiring high creep strength, consistent with long-term stability.

From its own modern foundries, B&W can supply alloy castings in practically any weight and shape required, and from a wide range of analyses.

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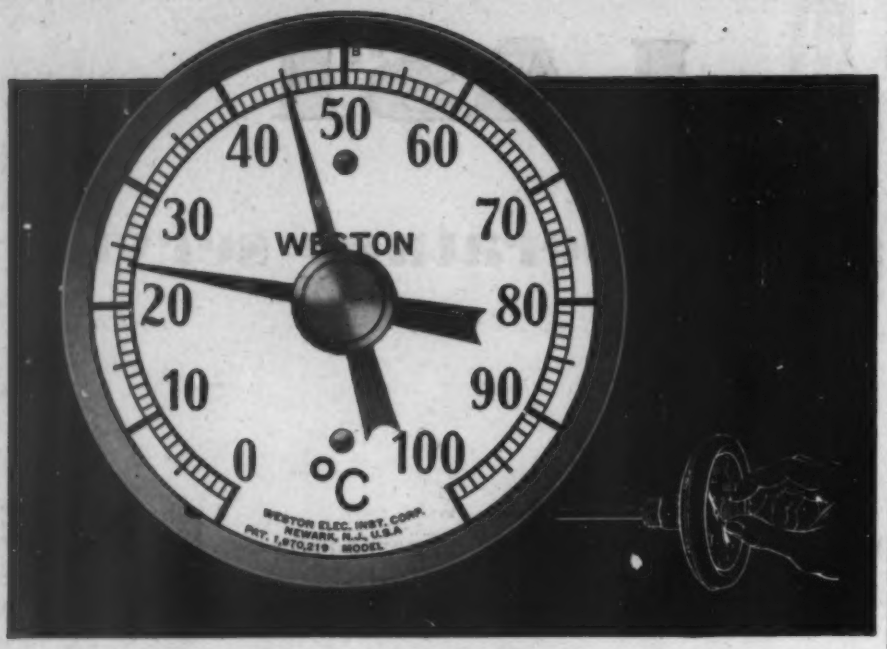

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What's the present processing temperature?

What was the highest temperature reached since last reading?

You want the answers to both these questions—and the **MAX-MIN** gives them... accurately!

The red index pointer on the **MAX-MIN** is manually set to either the low or high side of the main indicating pointer. When set on the high side, for example, it moves as the temperature increases, always remaining at the extreme temperature reached, until manually re-set. Thus one quick reading gives both *present* temperature and the *peak* temperature since last reading.

For complete details see your jobber or local Weston representative. Weston Electrical Instrument Corporation, 655 Frelinghuysen Avenue, Newark 5, New Jersey.

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THE MONTH...

tries in the Gulf Coast and adjoining areas.

The program being worked out for the second course is being drawn on the engineering level. Speakers will be drawn largely from the personnel of operating companies.

Further information as to accommodations can be obtained through Dr. P. G. Murdoch of the Chemical Engineering Department at Texas A. & M. College.

Gas Division Meet

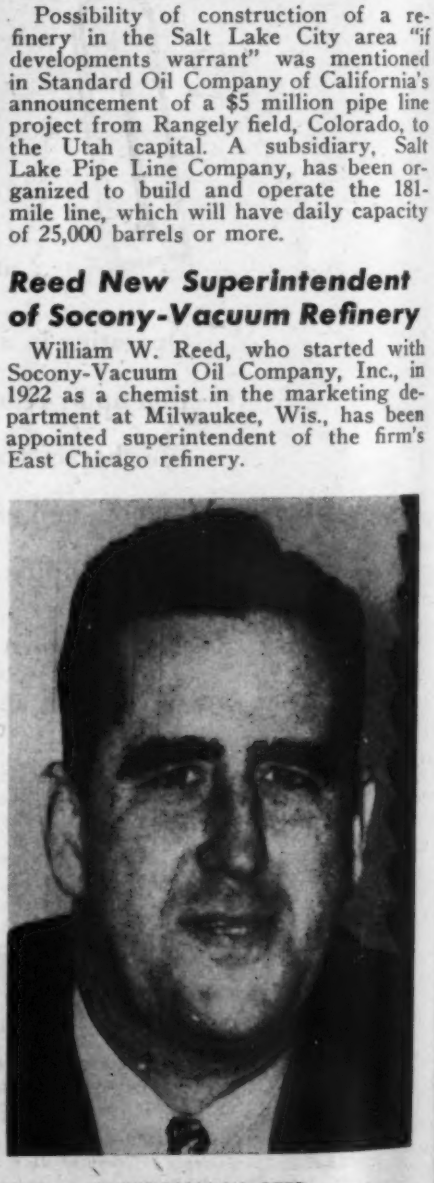
The annual one-day conference of the Gas Division of the Oklahoma Utilities Association will be held Friday, September 19, at the Biltmore Hotel, Oklahoma City, according to D. W. Reeves, chairman.

Standard of California Considers Salt Lake Plant

Possibility of construction of a refinery in the Salt Lake City area "if developments warrant" was mentioned in Standard Oil Company of California's announcement of a $5 million pipe line project from Rangely field, Colorado, to the Utah capital. A subsidiary, Salt Lake Pipe Line Company, has been organized to build and operate the 181-mile line, which will have daily capacity of 25,000 barrels or more.

Reed New Superintendent of Socony-Vacuum Refinery

William W. Reed, who started with Socony-Vacuum Oil Company, Inc., in 1922 as a chemist in the marketing department at Milwaukee, Wis., has been appointed superintendent of the firm's East Chicago refinery.



WILLIAM W. REED

Reed succeeds William Hildebrandt, who retired under the Socony-Vacuum pension plan and who, during World War II, was Indiana State Chairman

THE MONTH . . .

for the Committee on Protection of Petroleum Facilities, Great Lakes region. He became superintendent of the East Chicago refinery in 1926.

Four years after his first position in Milwaukee, Reed was transferred to the East Chicago refinery. He became assistant superintendent in 1932. He attended the University of Wisconsin and University of Indiana.

Shell Chemical Corporation to Produce Hexylene Glycol

Construction of facilities for the manufacture of hexylene glycol is under way at the Houston plant of Shell Chemical Corporation, according to B. M. Downey, plant manager. Full production is expected early in 1948.

This plant, being built by the M. W. Kellogg Company, is an addition to the $25 million expansion program previously announced for Shell Chemical.

At present the major uses of hexylene glycol are as a component of hydraulic brake fluids, in the manufacture of printing inks, and as a coupling agent or penetrant in textile processing. Other uses under investigation are as a component of engine cleaners, soluble oils, prespotting soaps, grinding aids and adhesives.

Shell Chemical Corporation Lists Transfers, Promotions

E. W. Casagrande has been named assistant plant superintendent of the Dominguez refinery, Shell Chemical Corporation, being succeeded as operations department manager by P. Janssen, formerly chief technologist, a position now filled by R. S. Ray, Jr.

F. A. Horsley, former senior technologist in the head office, has been named assistant plant superintendent at the Martinez refinery and W. G. Reynard has succeeded him. G. A. White succeeds Reynard as operations department manager.

Other Shell Chemical changes include transfers: N. Nardolillo, from first-class machinist to maintenance assistant foreman, Shell Point; F. H. Benzel, from clerk to chief clerk, Dominguez; W. Fette, from maintenance assistant foreman, Shell Point, to engineer, Houston; and D. H. Walbolt, junior technologist, from San Francisco to New York.

LPG Group Elects

Officials of the Liquefied Petroleum Gas Association, elected at the recent annual meeting in Chicago are: Tallent H. Ransome, Ransome Company, Emeryville, California, president; Walter Naumer, Carbide & Carbon Chemicals Corporation, New York; Kennety H. Koach, Green's Fuel, Inc., Sarasota, Florida; D. D. Purrington, Oklahoma, California; Lon Turner, Denver, Colorado; E. J. Gustafson, Sioux Falls, South Dakota, and W. G. Petty, Sr., Memphis, Tennessee, vice presidents.

Charles O. Russell, Thermogas Company, Inc., Des Moines, who retired as association president, was elected treasurer. Arthur Kruetzer, was reelected secretary and assistant treasurer.

Tells of 300 percent Rise In Refinery Investments

Increase in investment costs for refineries was pointed out by L. H. Harvison, executive vice president of M. W. Kellogg Company at a meeting of science editors last month at Jersey City.

"Due to war interruptions, there has been no major modernization to meet commercial market needs for the past five years," he said. "In ordinary times modernization could be financed through normal amortization and from surplus.

"However, the rapidly increasing scale of costs through these same years has created an abnormal financial situation. Just 10 years ago the most modern refinery required an investment of less than $8 per gallon of daily gasoline output. Today the same investment is about $25. Amortization funds based on an $8 investment thus are inadequate to meet present high costs and high present-day profits are absolutely necessary to make up the difference in investment costs."

Bulletin Completed for Natural Gas Measurement

The tentative standard for the measurement of natural gas as worked out by three West Coast associations is being printed and shortly will be ready for distribution. The work is listed as TS-461, "Tentative Standard Procedure for the Determination of Superexpansibility of Manometer Factors Used in Measurement of Natural Gas by Orifice Meter at Pressures in Excess of 500 psig."

The work was done by a committee,

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ALL-PURPOSE
STEEL VALVES

NEGLIGIBLE PRESSURE DROP

Large port openings are provided, thereby assuring little pressure loss through a WEDGEPLUG Valve. Openings in percent of pipe area are:
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WEDGEPLUG Valves are so designed that pressure-drop is reduced to a minimum, and is definitely not a limitation.

WEDGEPLUG offers the only real "All-Purpose" Valves on the market today—through the development of a simple, patented Dry Plug Valve that combines the best features of a Plug Valve with those of a Gate Valve: Large port openings; wedging action; raised seats; and, an easy-to-operate mechanism that *lifts, turns, and re-seats the Plug in one operation.* A Plug-type Valve that can take the place of a Gate Valve. Tried and proved under widely-varying service conditions. Write for Bulletin No. 545.

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Other Good Territories Now Open for Sales Representation

THE MONTH...

headed by E. P. Valby and represents the joint effort of California Natural Gasoline Association, Pacific Coast Gas Association and Southern California Meter Association. The work was done as a supplement to previous bulletins TS-353, TS-354 and TS-402.

Welch Retiring, Baity Is Standard Indiana Director

R. F. Baity, assistant general manager of sales for Standard Oil Company (Indiana) has been elected to the board of directors. Baity joined Standard in 1920 as a service station attendant.

L. C. WELCH

Dwight F. Benton, assistant general manager of lubricating and sales technical service departments, has become head of those departments succeeding L. C. Welch, who is retiring. Welch joined Midwest Refining Company in 1917 as chief engineer of refinery construction at Casper, Wyo., and became general manager of lubricating and sales technical service in 1944 at which time he was named to the directorate.

Simpson Succeeds Keyser In Socony-Vacuum Position

Paul V. Keyser has been named manager of the lubricating oil department, Socony-Vacuum Oil Company, Inc., succeeding H. S. Merriman, who becomes a member of the national accounts department.

At present Keyser is director of the company's Research and Development Laboratories, Paulsboro, N. J. He will be succeeded by Thomas P. Simpson, now assistant director of the Research and Development Laboratories.

Keyser was graduated from Massachusetts Institute of Technology and Simpson is an alumnus of California Institute of Technology.

Simpson was graduated in 1924 as chemical engineer from the California Institute of Technology.

In other advancements, Arlie A. O'Kelly becomes associate director in charge of the chemical division; G. H. S. Snyder, assistant director in charge of the lubricating oil division; Louis P. Evans, supervisor of the process development division, and John W. Payne, associate supervisor.

Tight Petroleum Supply Situation Brings on General National Discussion

As July opened, the domestic oil supply situation took high billing in Congress. The House Merchant Marine Committee threatened to investigate exports of petroleum to Russia, the Senate had one investigation scheduled and another being sought and the House Interstate and Foreign Commerce Committee heard Max W. Ball, director of the Interior's Oil and Gas Division, defend the oil industry for expanding its refinery output.

Ball, admitting that the Middle West likely would have a tough time next winter, explained why the country faces spot shortages or worse of gasoline, liquefied petroleum gas and burning oils. Lack of steel has hindered refinery expansion, badly needed as demand has risen to record heights.

"Basically, the situation results from a lack of steel for pipe lines, refinery equipment, new wells and tank cars," the OGD director declared. "Nine thousand new tank cars are badly needed, with present production ranging only 100-150 cars monthly. Increased output of these cars, already scheduled, will remedy the situation but slowly.

"This year the U. S. will be a net importer of oil on balance, with imports running about 482,000 barrels daily and exports just over 400,000."

Boatwright Optimistic

An optimistic note was sounded by John W. Boatwright of Standard Oil Company (Indiana) who said that if present refinery operations can be continued without interruption, the tight gasoline situation will be relieved in a few months. The problems to be licked are those of getting excess production to idle refineries and of getting products to consuming markets, he said.

In Minneapolis, Walter S. Hallanan, chairman of the National Petroleum Council told the API Marketing Committee that there is no over-all shortage of oil or its products and none in prospect, that "our production and refining facilities, although strained to the utmost are adequate to meet the present rate of consumption and any reasonable anticipated growth in demand."

"We are called upto the meet a record demand for petroleum products at a time when dislocations in other industries make it impossible for us to obtain materials for expansion of facilities needed to put our house in order," Hallanan declared.

Holman's Views

Meanwhile, Eugene Holman, Standard Oil Company (New Jersey) president, speaking at the same Minneapolis meeting declared "there is no basic shortage of petroleum," pointing out that "the shortages we are talking about result from the industry's difficulty in closing a small but significant gap between a record supply of petroleum products and a record demand for them." He added that in his opinion that gap would be closed.

Refinery runs should average about 5.2 million barrels daily during the quarter ending September 30, Holman declared, to have as much heating oil and other product stocks next October as the nation had last year. If the industry succeeds in getting ready now for the heating season, it might even be possible to slack off a little in crude and refinery runs during the October-April period and still reach April with adequate gasoline stocks, he thought.

"However, the industry should operate at maximum rates until it is sure future public and government needs can be met comfortably," he said.

Holman, Hallanan and B. L. Majewski, API marketing vice president, agreed that industry-wide coordination of a degree that would require approval of the Department of Justice is neither necessary nor desirable in the present supply situation.

Hallanan said that the nation's military forces while not satisfied with their supply situation were contented with the industry's response and the services feel that they will get what they need.

Petroleum Export Controls Again Are Imposed by OIT

Reimposition of export controls of aviation and other motor fuel, and gasoline, kerosine, gasoil and distillate and residual fueloil, etc., was ordered early this month by the Office of International Trade following pressure activated by reports of shipments to Russia. OIT officials did not want export control, saw no need for it, but realized that if they didn't act, Congress would.

In the meantime OIT is studying the matter of quotas by countries covering a period of two or three months or perhaps longer, this in recognition of time required to arrange for tankers.

Anglo-American Pact Given Senate Committee Approval

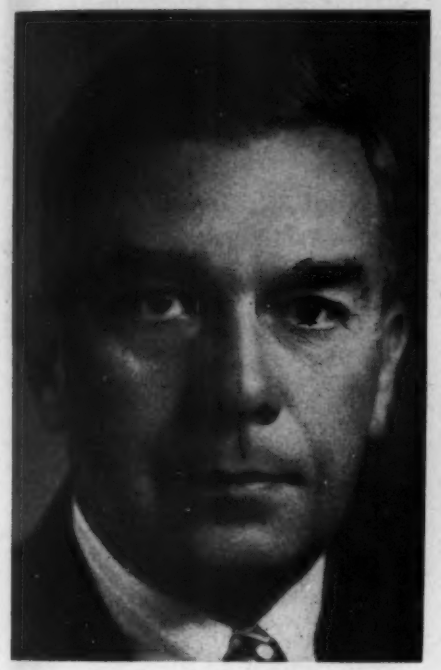
The Anglo-American petroleum agreement has been approved by the Senate Foreign Relations Committee, but whether the pact will be brought to the Senate floor for ratification before Congress adjourns was somewhat in doubt. Adjournment is scheduled July 26.

The committee wrote into the pact both the API reservations and two additional ones prepared by Chairman Arthur Vandenberg of Michigan, all designed to protect the domestic industry.

These revisions make it clear that neither the government nor Congress will derive from the pact any powers additional to those now possessed, that either U. S. or Great Britain may impose tariffs or quotas on oil imports, that the proposed international commission shall have no authority over domestic oil controls, that Congress shall not encroach upon the regulatory powers

of the states and that existing international concessions, agreements and contracts shall not be affected.

The State Department does not anticipate any difficulty in obtaining British acceptance of the changes. Department officials declared the reservations "entirely satisfactory," none of them changing the basic purposes of the pact.



FRANK J. COLTON

Colton Elected President Of Natural Gasoline Group

Frank J. Colton, president and W. A. Kirk, vice president and head of the advisory committee, new officers of the California Natural Gasoline Association formally took office July 8 at the annual directors meeting held in Los Angeles.

Colton, superintendent of gas operation, Tide Water Associated Oil Company, has been active in association affairs since 1935 and last year was chairman of the advisory committee. Kirk is connected with California Southern Oil Company.

New directors, elected for two years, include: A. H. Bradford, West Coast Refining Company; John G. Braun, Braun Corporation; F. J. Colton, Tide Water Associated Oil Company; Earl Dunn, The Fluor Corporation, Ltd.; R. C. Enderly, Wilmington Gasoline Company; M. L. Fort, Pacific Lighting Corporation; C. D. Gard, Union Oil Company; R. D. Gibbs, Union Oil Company; R. W. Heath, Signal Oil & Gas Company; J. C. Herron, Shell Oil Company; H. R. Linhoff, Richfield Oil Corporation; S. F. Magor, Superior Oil Company; P. S. Magruder, General Petroleum Corporation; H. W. Parmelee, Del Valle Gasoline Company; W. W. Robinson, Jr., The Texas Company; W. D. Smith, Wilshire Oil Company; R. S. Tulin, Shell Oil Company; E. W. Walker, Western Gulf Oil Company; E. W. Webb, Continental Oil Company.

Third of Oil Companies' Projected Two-Year Expenditure Is For Refining

Capital investments of more than four billion dollars will be made by the petroleum industry in the United States during 1947-48 for new facilities to serve increasing demands for all kinds of oil products, William R. Boyd, Jr., president of the American Petroleum Institute, announced late in June.

Such an outlay in the two-year period will represent more than 22 percent of the total investment of about $18 billion in the oil industry, the country's second largest.

The projected capital investment in 1947-48 is based on a survey of a number of companies which have actually budgeted outlays totaling more than $3 billion.

Capital investments will be made in the four divisions of the industry, all of which with the exception of crude oil production, are at practical, or close to, maximum operating capacity. On the basis of reporting company figures about $2 billion will be used in production (including exploration and the acquisition of prospective oil-bearing lands); slightly more than $1.1 billion in refining; about $440 million in transportation; approximately $480 million in marketing, and about $75 million for miscellaneous purposes.

Gas and Coal Conversion

A sizeable portion will be used also for progressive research with an eye to the development of new and improved products, including work on processes for the conversion of natural gas and coal into liquid petroleum products.

Funds for the major part of this expansion program will come from earnings to be "plowed back" into the business and a part, probably, will come from new financing.

Several factors account for the industry's current record expenditures. One is the unprecedented growth in demand for products which has reached levels far higher than had been anticipated, and another is inability to proceed with normal expansion programs because of the war. Postwar restrictions on essential materials still continue and will remain for sometime to come. Today there are shortages of steel, drill and line pipe, and most of the other materials needed by the industry.

From the standpoint of demand, wartime peaks, which were not expected to be approached for several years, actually were topped in the latter part of 1946 and the upward spiral has continued into 1947. Such demand-creating factors as high employment and income levels, rapid installations of oil burners and diesel engines, widespread farm mechanization, an almost insatiable public demand for travel by automobile, together with heavy industrial and foreign demands all combined to lift the total far in excess of that expected.

Accounting in part for the higher expenditures, too, are increased labor and material costs all along the line as compared with prewar years. Developmental costs of producing oil are far in excess of costs in prewar years; refinery equipment which cost $400 a barrel of capacity prewar now costs more than $1000 a barrel; pipelines which cost $12,000 a mile now cost $30,000 a mile, and marketing facilities now cost more than twice as much as in prewar.

The largest expenditures in 1947 and 1948 will be in production, the total amount spent by the entire industry in this category probably accounting for about 45 percent of the overall capital outlays.

Refining Expenditure

In the refining division of the industry, close to 30 percent of the total capital outlays during 1947 and 1948 will be made. The costs of new construction in this division are about three times those of 1936 and seven times those of 1916. Modern equipment includes highly complicated and specialized units such as catalytic cracking plants which have made important contributions to the yield and quality of gasoline; polymerization plants which make possible many thousands of barrels daily of high quality gasoline from refinery gases which, in the past, were wasted or burned as fuel; and alkylation units, a relatively recent development, which convert other gaseous constituents into gasoline.

As the president of one company recently stated regarding developments in refining techniques; "The more wonders our technologists perform, the more dollars are required to put their ideas into operation." But in most instances the higher costs have been offset by better quality and more important products, and prices have been maintained at reasonable levels.

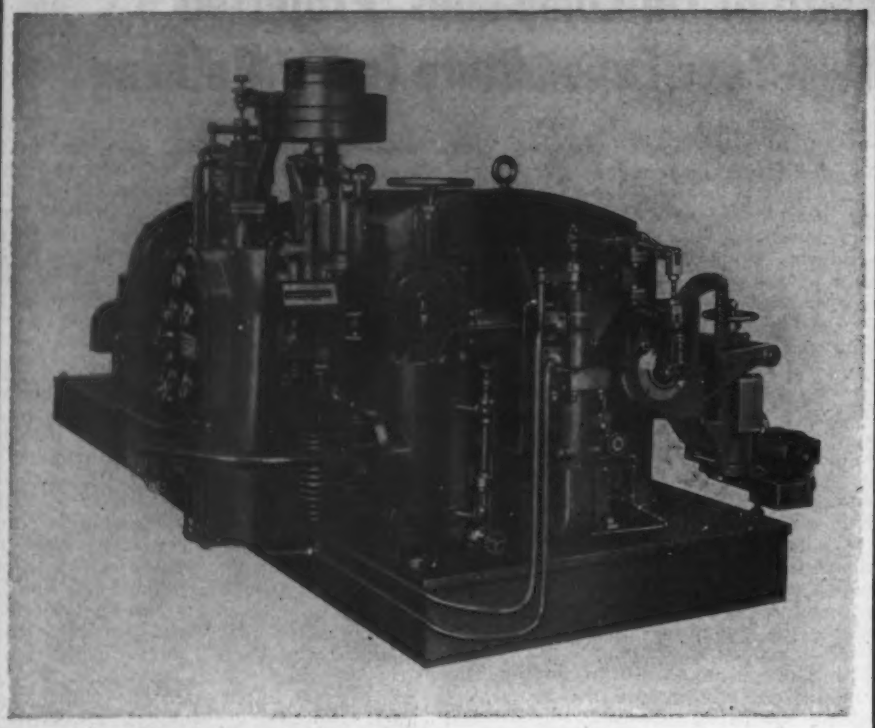
A recent survey discloses that the country's refining industry, which comprises close to 500 refineries scattered throughout 36 of the 48 states, has already announced plans to initiate construction within the next two years of 407,000 barrels-a-day of new capacity. Of this total, 100,000 barrels will represent replacements of obsolete or worn-out refineries, while the remaining 307,000 barrels-a-day will represent new and additional refining capacity. Announcement of other new plants is expected in the not-distant future.

While the industry made substantial capital investments during the war in facilities for the manufacture of special products needed to prosecute the war, such as high octane aviation gasoline, toluene and others, this wartime capacity has not added appreciably to civilian production capacity, although it has made possible increases in product quality.

In the field of transportation, where the industry has been responsible for developing its own unique facilities in pipe lines and tank ships, as well as barges, tank cars and tank trucks, roughly 11 percent of the industry's outlays will be used. Marketing, which takes in service stations and bulk terminals of the oil companies, will consume approximately 12 percent of expenditures, with the remaining 2 percent to be used for miscellaneous purposes.

Tanker Legislation

The government's tanker operating authority has been extended by legislation, signed by President Truman, and thus the U. S. Maritime Commission



LARGE TURBINE PERFORMANCE FOR THE **SMALL** PLANT

An outstanding advantage of Murray Turbines is that they give the small plant many of the desirable operating economies enjoyed by larger plants.

The illustration above shows a typical job of this kind—a 175 KW Murray Extraction Turbine installed in a midwestern packing plant.

This modern unit operates with steam at 235 lb. pressure—500 deg. F. total temperature, and exhausts at 27 in. vacuum. Steam is extracted automatically at 60 lb. pressure.

Let our engineers cooperate in smoothing out your power problems.

MURRAY IRON WORKS COMPANY

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Builders of Steam Power Equipment For Three Quarters of a Century

THE MONTH...

will be able to keep surplus tankers in service until next March 1 on a general agency or voyage-charter basis.

Chairman Weichel of the House Merchant Marine Committee made it plain that the committee regards continuation of ship operating authority for the next eight months as "a resonable period for final extension.'

The committee also wants the commission to reduce its operating fleet to a maximum of 150 tankers within the next three months, with a further reduction to follow as additional tankers are sold abroad. It also asks for substantial reduction in present rates for carrying of petroleum products aboard these tankers.

Federal Agencies Studying Tidelands Opinion Effects

Interior and Justice department officials, following the Supreme Court's decisions vesting California tidelands title in the federal government, were struggling with the problem of federal policy with respect to the California areas involved. A new study of the question from the angle of possibilities of its future application to the underwater lands of other states is said to be under way, this because of the sweeping nature of the court's decision.

Legislation was drafted to return title to the state but there is some question in Washington whether it is adequate to cover the court decision and, also, whether it could be enacted over a certain Truman veto.

As a result of the court decision, Congress must decide whether to surrender federal claims to the offshore lands or provide for a new relationship between the federal and state governments with respect to such properties with federal control of underwater oil and other resources.

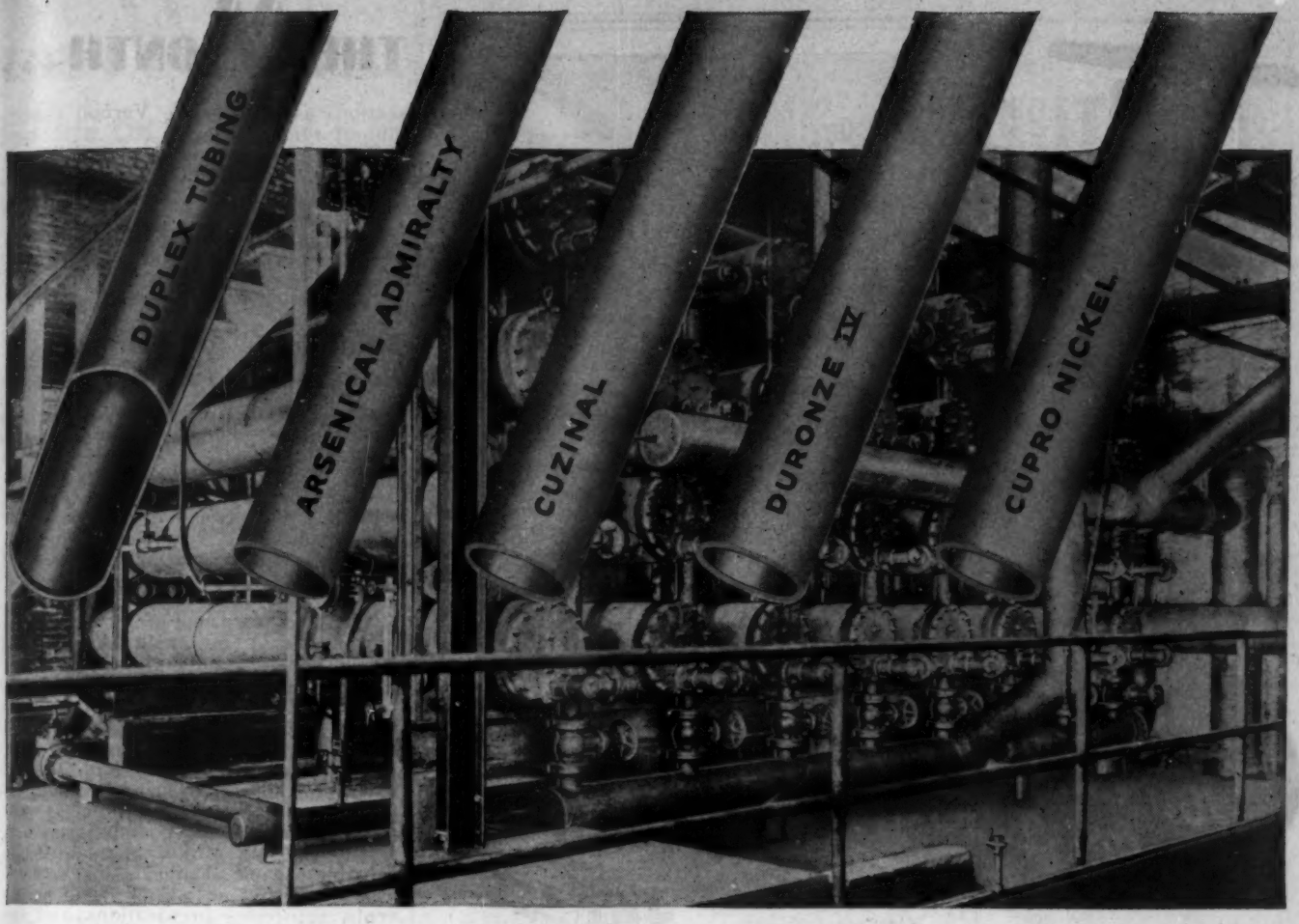
The administration is said to favor the plan of making a naval petroleum reserve out of such of the California oil bearing tidelands as are not now being exploited, but it is likely that any action along this line will be deferred until the next session of Congress.

Rowsey, Melasky, Forgan Are Named Directors of Firm

G. L. Rowsey, Harris A. Melasky and Glenn Forgan have been named directors of Petroleum Heat & Power Company which recently acquired Taylor Refining Company, Taylor, Texas, of which Rowsey is president and Melasky, vice president. The Taylor firm announces that it will, under its present officers, continue its corporate existence and its petroleum production, transportation, refining, and marketing activities with general offices at Taylor, Texas.

General Petroleum Makes Laboratory Staff Changes

J. G. Schaafsma has been named assistant to the manager of laboratories of General Petroleum Corporation and the process and economics sections will report to him. Bert Folda, Jr., has been promoted to a similar position and will supervise the chemical and lubricants



REDUCE CORROSION WASTE

The toll of corrosion in petroleum refining and chemical processing industries involves much more than the tubing cost alone. It is aggravated by loss of production, extra cost of maintenance and product contamination associated with failure of tubing or pipe lines.

To help reduce waste, Bridgeport maintains a consistent program of laboratory research, as well as field and service tests, and works closely with chemical and operating engineers on their corrosion problems.

A number of fine condenser and heat exchanger tube alloys are available to meet a wide range of conditions. For oil refining, Arsenical Admiralty has been a consistent, good performer. Arsenical Muntz* is especially resistant to high sulfur corrosion. High water velocities with the danger of impingement corrosion can be dependably handled with Cuzinal (Aluminum Brass). Duronze IV** gives fine service withstanding hot brine or circulating sea and brackish water. Duplex Tubing is available for double corrosion, where two different types of corrosive attack, both inside and outside, are too much for a single alloy. It is made up of two different metals, each designed to combat the specific type of corrosion involved.

We will be glad to help you select the tubing to solve your particular corrosion problem. Contact the nearest Bridgeport office, and write for the informative Condenser Tube Manual and the Duplex Tubing Technical Bulletin.

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A thorough check-up now will pay dividends. And don't overlook your steam, water, and air lines. A sudden valve failure might mean loss of valuable power and production.

But should valve trouble occur, you can get help . . . quickly . . . from your near-by Lunkenheimer Distributor. Long established in the community, he has thoroughly experienced personnel and adequate stocks . . . all the facilities and "know-how" for solving your valve problems.

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THE MONTH . . .

sections as well as the Vernon control laboratory.

Schaafsma is a graduate of California Institute of Technology and has been on the staff of General Petroleum Corporation since 1935.

Folda joined the company in 1934 after graduation from Leland Stanford University and recently has been supervisor of the chemical lubricants section.

Stanolind's Program at Hugoton Told by Forrester

Stanolind Oil & Gas Company will be producing gasoline from natural gas in the Hugoton field in 1949, J. H. Forrester, manager of the company's manufacturing branch, told 150 key scientists of Standard Oil Company (Indiana) and its subsidiaries at the recent meeting in French Lick Springs, Ind. Detailed engineering for the synthol plant is nearing completion, he said.

"The new plant will produce 5300 barrels per day of high-quality gasoline and in addition by-products made each day will include 800 barrels of fuel oils, 1060 barrels of light hydrocarbons and a half-million pounds of chemicals," he declared.

J. E. Latta of the Stanolind's Tulsa laboratory, in discussing chemical by-products of the synthol process, said, "The oxygenated compounds formed are a potential source of large quantities of valuable organic chemicals. These materials are useful in various fields as solvents, anti-freeze preparations, and raw materials for the manufacture of fine chemicals. Included are alcohols, ketones, organic acids and aldehydes, many of which have widespread commercial use."

Labor-Management Act Topic at Three Meetings

The Industrial Relations Department of the Western Petroleum Refiners Association is holding a series of meetings to discuss details of the recently passed Labor-Management Relations Act. The first meeting was held July 11 in Wichita, Kan., and the other two regional meetings are slated as follows: July 17, Olds Hotel, Lansing, Mich., and July 25, Blackstone Hotel, Fort Worth.

Charles Kothe, Tulsa attorney, who spoke in Wichita, also will speak in Fort Worth while Carl Metz, Jr., of the Industrial Relations Department of Standard Oil Company (Ohio) will speak in Lansing. James T. Rasbury, the association's industrial relations director, is giving a summary of what is contained in the new law.

Chile Would Buy Plants To Handle Spring Hill Oil

Fred Morrison, representing British firms in Buenos Aires, is due to go to Santiago, to confer with government officials regarding purchase by Chile from Great Britain of one or two oil refineries.

Purchase of a refinery from the United States also is planned, all these plants being regarded as needed to handle the eventual output of the Springhill oil field in extreme south Chile where three wells are now said to be producing some 2000 barrels daily.

THE MONTH...

Seaside Oil Head Dies

Harold B. Kellogg, 54, president of Seaside Oil Company, Santa Barbara, California, died June 4 at his home. Kellogg was born in Emporia, Kansas, and started his college training at Kansas University. His family moved to California and he was graduated from the University of California.

His first business activity was with the Associated Oil Company, where he worked until he joined the army in World War I. Later he rejoined that firm and was in its employ until 1936 when he became vice president of Seaside Oil Company.

J. R. Battenfeld Dies

J. R. Battenfeld, 58, one of the founders and first president of the National Lubricating Grease Institute, died in Kansas City, Mo., May 7 after an extended illness. Battenfeld started in the lubricating grease and oil business 40 years ago and built "from a shoe-string the Battenfeld Grease and Oil Corporation of Kansas City., which is one of the larger manufacturers of lubricating grease in this country. He was a charter member and past president of the Oil Men's Club of Kansas City. At the time of his death he was a director and chairman of the membership committee of the National Lubricating Grease Institute.

EFCO Gives Barbecue

Some 200 operating executives and engineers from Gulf Coast refineries and chemical plants were guests at a barbecue given by Engineers & Fabricators (EFCO) at their plant June 27.

In addition to an open house showing various stages in the manufacture of heat transfer equipment, two new electronic devices to measure the thickness of metals were demonstrated.

These two devices, the "audigage" and the "penetron," resulted from wartime developments in electronics. They promise to be most valuable around refineries and process plants, officials said.

Phillips Buys Control Of Two Western Plants

Phillips Petroleum Company of Bartlesville, Okla., will hereafter control both Wasatch Oil Refining Company of Salt Lake City and Idaho Oil Refining Company of Pocatello, Idaho, as a result of a stock exchange deal.

Henry D. Moyle of Salt Lake City, heretofore vice president of both Wasatch and Idaho, will become president of both firms which will continue to market their products under their own trade names. Phillips' production in the nearby Rangely, Colo., field will be added to that of the the intermountain firms.

Gasoline Plant Sold

Magnolia Petroleum Company's natural gasoline plant near Sunray, Moore County, Texas, has been sold to Shamrock Oil & Gas Corporation for $180,000. The property coptains about 30 acres.

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● It looks as clear and bright as the desert on a sunny day — when you look at the new Palmer Thermometer. The new Extruded Brass Case plus famous "Red-Reading-Mercury" does the trick! You get a standard beautiful chrome finish at no extra charge . . . a full, easy-to-see scale with large, clear numerals, offering visibility never before available.

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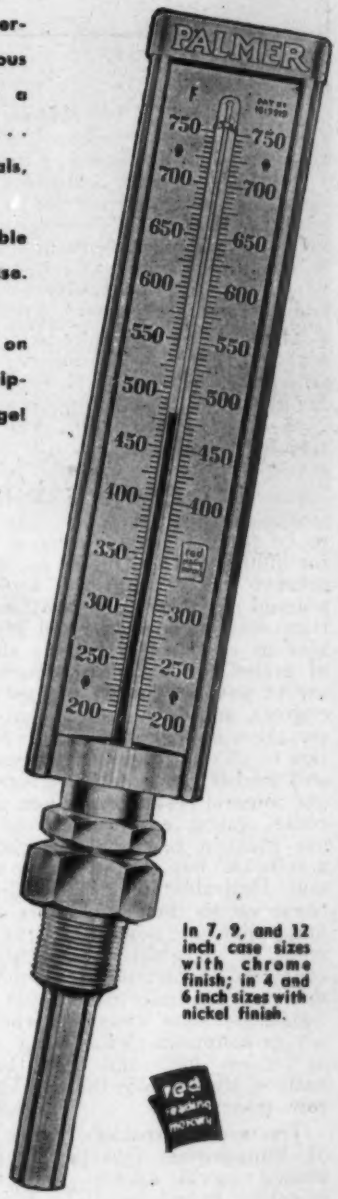
Fully compensated 8" round case. Standard dials available for all ranges. Equipped with micrometer adjusted hand. Atomic welded construction.



In 7, 9, and 12 inch case sizes with chrome finish; in 4 and 6 inch sizes with nickel finish.

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Abstracts of Some of the Papers Presented Before Division of Petroleum Chemistry, American Chemical Society Kansas City, Missouri, June 23-25

THE FIFTEENTH Midwest regional meeting of the American Chemical Society was held in Kansas City, Missouri June 23, 24, and 25, and drew an attendence of chemists from all parts of the country, who heard reports of new developments and methods in the fields of agricultural chemistry, industrial chemistry, chemical education and history and petroleum chemistry.

The sessions were initiated with a general meeting the morning of June 23, at which Willard M. Hoehn, secretary for the regional meeting, presided and Nicholas Dietz, Jr., chairman for the regional meeting, introduced the speakers.

Harold Vagtborg, of Midwest Research Institute, talked on the problems to be faced in supplying raw materials for industry in the future as the world's present resources are depleted. He pointed out that, even now, some countries without adequate fuel reserves resort to expedients such as the raising of grains for combustion fuels and the use of powdered corn as fuel for diesel engines, and he suggested that true conservation involves the maximum utilization of all our resources, especially crops and timber, as a valuable extension of our mineral resources. When metals become scarce, extraction from the sea, our greatest reservoir, will possibly be a solution, but careful use is all important. Desirable steps in the direction of conservation include digging deeper to find what we now have, the development of marginal operations once not considered economical, and the development of synthesis to provide new materials and new ways for producing existing materials. Vagtborg expressed agreement with the idea that debtor nations should pay their obligations in raw materials.

The second speaker, James G. Vail, of Philadelphia Quartz Company discussed moral aspects of the use of scientific knowledge. The high rate at which we have accumulated knowledge may be in excess of our ability to assimilate it. Science in itself is neither good nor evil, but technology, the application of science, does have either a harmful or helpful impact on the world community. World population has doubled in the last 100 years, now has one inhabitant for each two acres of land, a condition permitting adequate living for all if our present knowledge is used to good advantage.

The balance of the sessions for the regional meeting were concerned with technical reports for the several groups, with a number of group luncheons, and with a special evening program of entertainment.

Abstracts from several petroleum group papers are given on the following pages.

Composition of Petroleum: Hydrocarbon Type Analyses of Ten Distillates Boiling Between 100° - 600° F

By W. C. HOLLIMAN and H. M. SMITH

A comprehensive study of the distillates from ten of the more important crude oils of the United States, selected because their characteristics differed widely, was made during 1944-1946 by the Bureau of Mines to furnish information regarding sources of specific types of petroleum products. The ten crude oils selected for this study represented major production in the following fields: Coles Levee and Midway-Sunset, in California; Louden, in Illinois; West Edmond, in Oklahoma; Bradford, in Pennsylvania; and Conroe, East Texas, Hastings, Slaughter, and Yates, in Texas.

The study included the design, construction and use of special distillation apparatus which would provide large enough distillate fractions to permit the determination and comparison of many physical and chemical properties of the distillates not ordinarily made in the Bureau of Mines routine analysis. Detailed drawings of this special distillation apparatus are given in the report, together with a description of its operation.

An objective of the study was the development of computed functions, by a study of correlations between usually determined properties of the distillates and properties not ordinarily observed, that would amplify the applicable scope of the data obtained in the routine analysis and make it more useful in evaluating crude oils for specific and possible uses.

The Bureau of Mines routine analysis procedure was adopted by the Bureau of Mines more than twenty-five years ago, and has been used in the analysis of crude oils from almost every major field throughout the world. The properties determined on the crude oil analyzed according to the procedure include specific gravity, color, viscosity, and sulfur content. A portion of the crude is then distilled and separated into fractions at arbitrarily designated temperatures and pressures. The volume and specific gravity of each of the fractions and of the residuum are determined, as well as the cloud point, viscosity, and aniline point of some of the fractions. A correlation index value (C. I.) based upon the mid-boiling point and the specific gravity, is computed for each fraction and reported as a part of the analysis.

Observed properties of the distillate fractions, and of blends made from them, obtained by use of the special distillation apparatus, included those usually made in the routine analysis. In addition, the following properties were observed or calculated:

Distillation ASTM D-86; Density; Refractive index (3 wave lengths); Viscosity (at 3 temperatures); Aniline point; Freezing point; Sulfur content; Bromine number; Flash point; Molecular weight; Molecular volume; Aniline function; Molecular refraction; Dispersion; Specific dispersion; Refractivity intercept; ASTM ES-45a hydrocarbon type analysis; Silica gel hydrocarbon type analysis.

In the present paper data concerning the determined properties and computed functions of the ten selected crude oils and their distillate fractions and blends are presented in tabular form, together with a description of the apparatus and the methods of testing used. Data obtained in Bureau of Mines routine analyses of the same crude oils also are presented, and a chart is included which shows the percentage composition of the distillate fractions from the ten crude oils in terms of hydrocarbon types as estimated from the silica gel analyses and physical properties.

Ignition Qualities of Hydrocarbons In The Diesel Fuel Range

By A. D. PUCKETT and B. H. CAUDLE

Rapid increase in the use of Diesel engines, advent of gas turbine and jet type aircraft engines, and widespread use of catalytic cracking, all of which may compete for the same type and boiling range material for fuel and cracking stock, have aroused speculation as to whether ignition quality of future Diesel fuels can be maintained at present levels. In the event that, through economic or other factors, the supply of high quality Diesel fuel must be supplemented by synthetic products or maintained by improving the ignition quality of material not now considered suitable, necessity for information on the cetane numbers of hydrocarbons which can be synthesized or isolated from petroleum becomes apparent. It is the purpose of this paper to present a survey of the literature, making available the extant data on ignition quality and related properties of hydrocarbons

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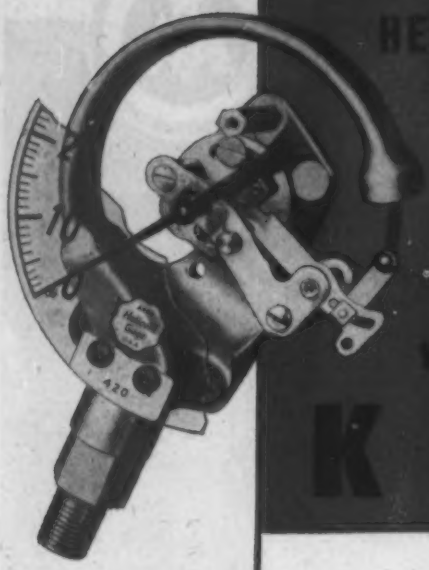

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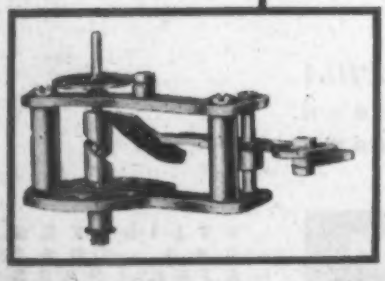

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which will influence their use in fuels for high speed Diesels.

Unfortunately, the presently accepted engine test for ignition quality of Diesel fuels (ASTM Designation D 613) is of recent development and comparatively few data obtained by this method, or, in fact, by any engine test method, are available. A. D. Petrov and co-workers in Russia, however, using the method of Michailova and Newmann, have determined the ignition quality of a number of compounds in terms of cetene number. The procedure followed is outlined in NACA Technical Memorandum No. 813, "The cetene scale and the induction period preceding the spontaneous ignition of Diesel fuels in bombs," by M. N. Michailova and M. B. Neumann, December, 1936. It consists of measuring the time lag between injection of the fuel into a heated bomb and its subsequent autoignition. This lag or induction period is converted to cetene number by use of a previous calibration. The originators of the method present test results showing excellent correlation with those obtained from a Waukesha engine.

Cetene numbers by the Neumann bomb and all engine determinations of cetene and cetane numbers that could be found in the literature are presented in tables which also show other properties of the hydrocarbons pertinent to their use in diesel fuels. The tables include data on paraffins, olefins, and aromatics.

These data indicate the following general trends with respect to correlation between chemical structure and ignition quality:

1) Normal paraffins have the highest cetane numbers.

2) Aromatics have low cetane numbers.

3) In the case of branched paraffins or alkylated aromatics, the lower the number of side chains down to a minimum of one, and the greater the length of these chains, the higher will be the cetane number.

Petrov states that his work points to mono-alkylbenzenes with long but inextensively branched chains and mono-alkyldacalins with short chains as being of major interest for aviation Diesel fuels.

Although determination of ignition qualities of all the many possible hydrocarbons in the Diesel fuel boiling range is neither practical nor necessary, spot checks of the Russian data by the present ASTM engine to determine correlation between engine and the bomb methods, and tests of relatively few additional compounds to fill gaps in the data appears desirable. Such a procedure would tend to strengthen the conclusions already drawn as to relation of ignition quality to structure and might permit their extension on a quantitive basis.

Superfractionation Study: Naphtha From Santa Barbara, Venezuela Crude Oil

By F. G. SCHWARTZ, R. M. GOODING, and B. H. ECCLESTON

The relation of composition of 0.5 percent fractions to their octane numbers, and the change in octane number of fractions as the distillation progresses is shown in this paper.

Approximately 100 gallons of a naphtha representing 22.12 percent of a Santa Barbara, Venezuela crude oil were superfractionated in a pilot plant batch.

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- ★ **CACTUS ORDNANCE WORKS** Dumas, Texas. Now operated by Emergency Export Corporation

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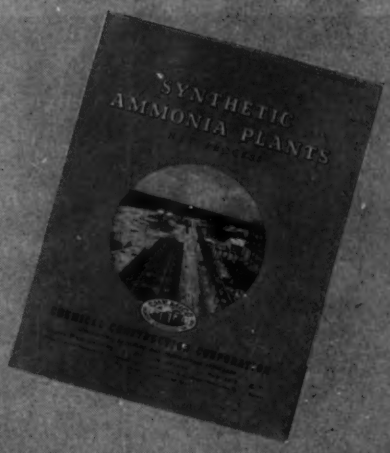

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still having the equivalent to eighty to ninety theoretical plates. The fractions were collected between 103° and 326° F. hydrocarbon composition of each was determined by use of specific dispersion and refractivity intercept and F-2 (clear) and F-3 (+4.0 ml. TEL) octane numbers of each fraction were obtained.

A figure is presented in which three curves are shown; a conventional distillation curve, a plot of F-2 octane number vs. fraction number, and a plot of F-3 octane number vs. fraction number. The composition of each fraction in terms of paraffins, isoparaffins, naphthenes, and aromatics is given in a bar graph at the bottom of the figure.

From the composition and determined octane numbers the blending octane numbers of individual hydrocarbons was calculated. These values and several other physical properties are presented in tables which include:

1) Inspection properties of Santa Barbara naphtha; 2) Charge data for Santa Barbara superfractionation; 3) Composition of Santa Barbara naphtha (103°-326° F. boiling range); 4) Blending octane numbers of hydrocarbons; (From Santa Barbara & Oklahoma City superfractionations); 5) Properties of isohexane, isoheptane, iso-octane, isononane, and isodecane cuts from Santa Barbara naphtha; 6) Properties of isocuts blended with isopetane; 7) Composition of isocuts from Santa Barbara naphtha; and 8) Calculated and determined octane numbers of isocuts from Santa Barbara naphtha.

Using blending octane numbers derived from this and preceding superfractionations, octane numbers of selected cuts may be calculated from laboratory superfractionations with an accuracy of ± octane numbers.

Fuel Volatility and Distribution Correlation With EAD Curve Characteristics

By CHARLES H. PRIEN and NORMAN A. PARKER[1] *University of Colorado.*

Although the effect of fuel volatility on general performance of an internal combustion engine has been extensively studied, relatively few correlations have been secured between fuel properties and cylinder distribution. The authors report the result of an intensive study of fuel-air mixtures, ethylene dibromide, and tetraethyl lead distribution in an aviation engine operating at air temperatures between minus 40° F and plus 34° F. Correlations are presented of individual cylinder distribution of the above three quantities, with the temperature and slope characteristics of the standard EAD curves of various aviation fuels. The effects of overall fuel performance, and the separate effects of carburetor air temperature and power are analyzed, and related to the physical properties of the fuel.

[1] Present address, University of Illinois, Urbana, Illinois.

The Relation of Motor Fuel Sensitivity And Tetraethyl Lead Susceptibility to Road Antiknock Performance

By JANE F. JORDAN and T. H. RISK, *Ethyl Corporation Refinery Division, Detroit.*

There is a definite tendency in the oil industry today to stress the research ratings of gasolines. This stems from the belief that high sensitivity in motor fuels (Research octane number minus motor method octane number) is an assurance of good road performance. This is true up to a certain point, but it may be very misleading to rely entirely on

high research ratings. High research ratings obtained at the cost of tetraethyl lead susceptibility are indicative of a type of hydrocarbon distribution throughout the boiling range of the fuel which may result in high speed knocking. Furthermore, such fuels may have lower road appreciation (road octane number minus Motor method octane number) than somewhat less sensitive motor fuels of good lead susceptibility.

Alumina Cracking Catalysts

By V. M. STOWE, E. E. MARSHALL, L. L. NICKEL[1] and R. S. GREENWOOD, *Aluminum Research Laboratories, East Saint Louis, Illinois.*

Kerosine was cracked over activated bauxite, activated alumina, and alumina impregnated with compounds of magnesium, boron, silicon and fluorine. Iron compounds in bauxities are deleterious, since they retard the formation of aromatic compounds, and use up the feed stock to produce gas and carbon deposit. Activated alumina, which contains practically no iron, gave better yields of higher quality gasoline than the best bauxites. Of the compounds added to the activated alumina, magnesia, chromium fluoride and zinc fluoride gave high yields of liquid olefins; magnesium fluoride gave gas of increased density; boric acid, ammonium fluoborate and fluosilicic acid gave high conversion rates. Best results were obtained with an activated alumina containing about 3 percent silica.

[1] Deceased March 26, 1947.

Petroleum—A Basic Raw Material Of The Surface Coatings Industry

By ROBERT F. RUTHRUFF, *The Sherwin-Williams Co., Chicago.*

The synthesis of a number of polyhydric alcohols, using gaseous hydrocarbons as raw materials, is described. The preparation of resins and of highly reactive (resin forming) unsaturated compounds from the same raw materials is mentioned. The use of liquid petroleum hydrocarbons in the synthesis of polycarboxylic acids is considered and some attention is given to the reaction of these acids with polyhydric alcohols to form alkyd resins. Some of the major difficulties involved in the synthesis of siccative oils from petroleum hydrocarbons are listed and the conclusion reached that such a synthesis is extremely difficult although not necessarily impossible. The imminent domestic production of Fischer-Tropsch liquid may well prove to be of great help in this and other syntheses.

Manufacture of Synthetic Gasoline

By SCOTT W. WALKER

The synthesis of gasoline by cobalt catalyst was discovered in 1923 by the Germans, Fischer and Tropsch. Development work in Germany resulted in a plant capacity of 11,400 barrels per day of low quality gasoline by 1938. The motive in the German development was strategic rather than economic.

Improvements in the Fischer-Tropsch process and use of low-cost natural gas and oxygen have resulted in an economic process for the synthesis of gasoline and by-product chemicals. The substitution of a fluidized iron catalyst for the German fixed cobalt catalyst has resulted in better heat control, higher quality gasoline, less undesirable products, and lower investment costs. Production of the synthesis gas by partial combustion of natural gas is an innovation which depends on cheap oxygen from the modified Linde-Frankl process, and is a more efficient process than methane reforming or the steam and coke method. Two synthetic gasoline plants are now in the design stage, and construction is to begin in the near future. It can be predicted that the utilization of this process to convert natural gas and, at some later date, coal to gasoline and chemicals will insure an adequate supply of liquid fuel in this country for many centuries to come.

Color Contamination of Petroleum Products Transported by Pipe Line

By L. V. SORG and R. E. DICKEY

A field trial of an experimental alkaline inhibitor, designed to minimize internal corrosion in pipe lines transporating petroleum products has been made. The use of this inhibitor was quite successful in reducing the amount of sediment removed from the pipe line system. Its use, however, in the pipe line system handling finished petroleum products, ranging from motor fuels to burning oils, gave rise to a most unexpected color contamination problem, which was most noticeable and objectionable in the case of water white products such as kerosene. The dye responsible for this discoloration of water white products was isolated and identified as p-indophenol. This dye is formed in the strongly alkaline corrosion-inhibitor phase and apparently results from a reaction between an oxidation product of the antioxidant used in motor fuels and phenol naturally occuring in petroleum stocks. These compounds are concentrated by the alkaline inhibitor phase. Concentrations of p-indophenol as low as one part in five million were found to impart an objectionable pink discoloration to water white petroleum products.

It was found that the addition of sodium sulphite to the corrosion inhibitor would eliminate the color difficulty without affecting the corrosion-inhibiting quality of the inhibitor.

Catalytic Desulfurization and Reforming Of Naphthas Over Bauxite

By G. M. BROONER and C. J. HELMERS

The problems of the refiner in meeting higher octane specifications for motor fuels are made more difficult by the current shortage of tetraethyl lead and the more prevalent use of high sulfur crudes. Where moderate or high sulfur stocks are processed catalytic desulfurization offers an economical means of utilizing tetraethyl lead more efficiently in both straight run and cracked stocks, due to the improvement in lead response effected by removal of sulfur compounds from the naphtha. If the desired rating cannot be attained through improved lead response alone the octane level can be raised by catalytic reforming of the naphtha, concurrently obtaining any benefits of improved lead response from simultaneous reduction in the sulfur content.

Catalytic Desulfurization

In desulfurizing straight run or cracked naphthas over bauxite the naphtha is vaporized and preheated to 725°-765° F. before passing through the bauxite bed wherein most of the organic sulfur compounds are decomposed with the evolution of hydrogen sulfide. Operating conditions are essentially the same whether the stock to be desulfur-

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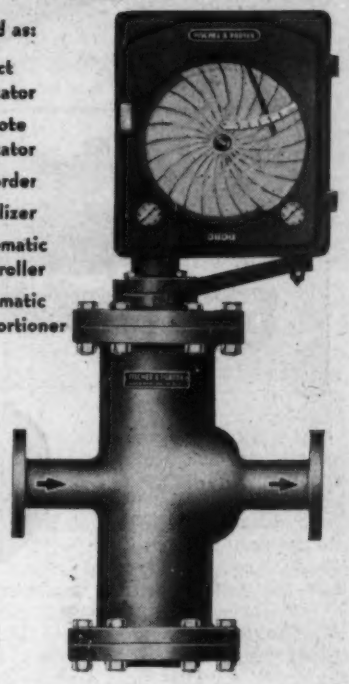

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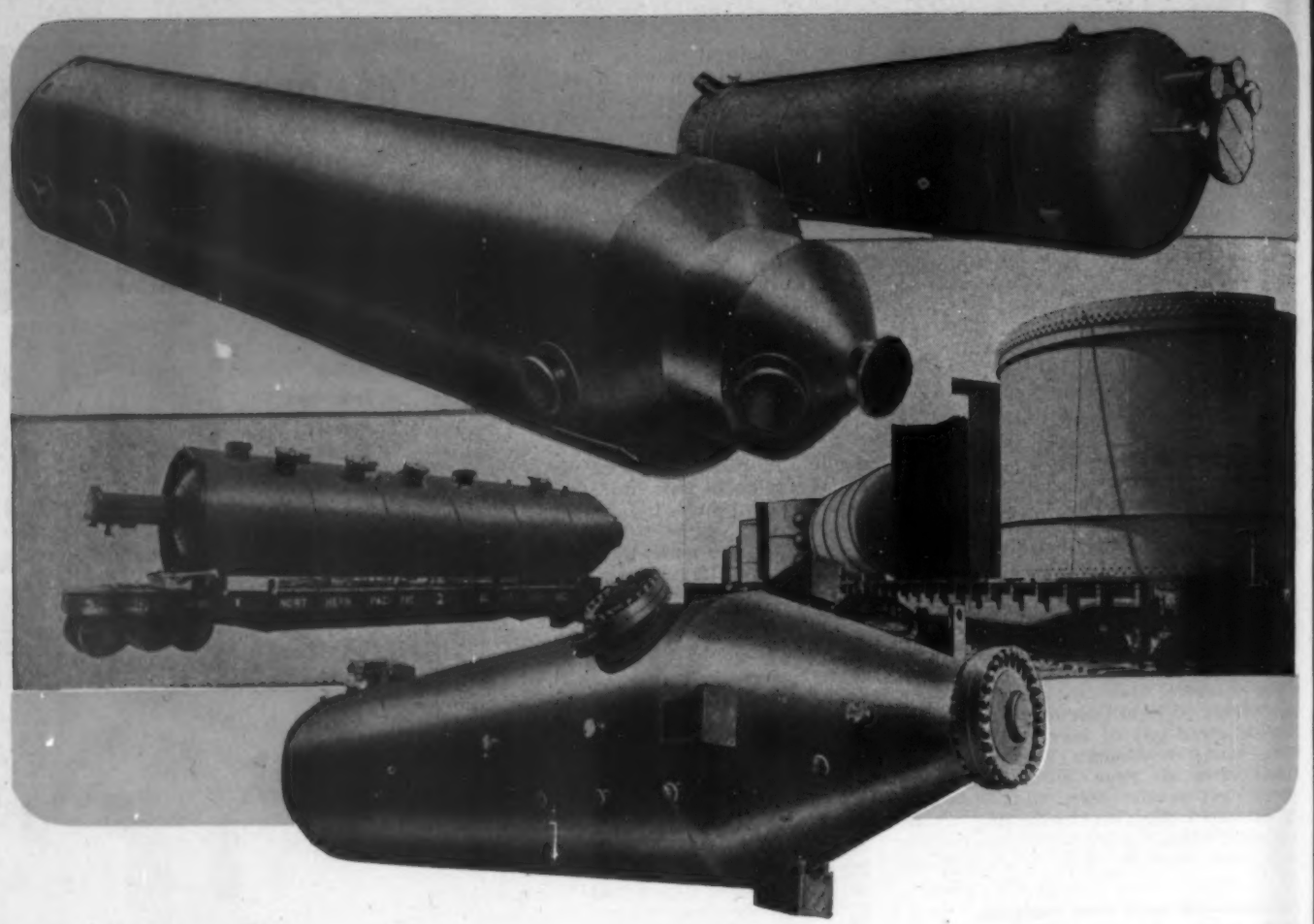

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ized is a natural gasoline, straight run naphtha or a cracked stock.

Desulfurization of a straight run stock removes from 75 to 95 percent of the sulfur and normally has little effect upon the unleaded octane rating unless the sulfur content is relatively high. With stocks containing 0.15 - 0.2 percent total sulfur an improvement of 4 to 7 octane numbers in the unleaded rating is not uncommon, the principal improvement, however, is noted in the leaded octane values. Depending upon the sulfur content of the naphtha and the extent of sulfur removal, desulfurization over bauxite improves the octane rating of the leaded gasoline from 2 to 10 units or more.

With continued processing carbonaceous deposits gradually accumulate and reduce the effectiveness of the bauxite catalyst. The rate of carbon deposition is primarily a function of the type and boiling range of the stock, high end point stocks having a higher rate of deposition than the corresponding low end point naphthas. The catalyst can be reactivated with an oxygen-containing gas although often times in desulfurizing straight run stocks it is relatively inexpensive to discard the catalyst since naphtha throughput normally ranges from 5000 to 15,000 barrels per ton, of bauxite before reactivation is required. At a throughput of 5000 barrels per ton, the catalyst cost amounts to about one cent per barrel of gasoline desulfurized.

Treatment of cracked gasoline over bauxite differs from the treatment of straight run gasoline in that sulfur removal is usually of the order of 40-60 percent and most of the octane improvement is obtained in the unleaded rating. As a result the octane improvement is essentially the same over the entire TEL curve. Octane improvement here is a combination of the benefits of sulfur removal and some molecular rearrangement or isomerization of the olefinic constituents and ranges from 2 to 8 octane numbers, depending upon the characteristics of the cracked naphtha. Due to the olefins in cracked gasoline carbonaceous deposits collect upon the catalyst much more rapidly than in the case of a straight run or natural gasoline, normally amounting to about 0.25 percent by weight of the charge in a 24-hour period. Operation for periods of 24 to 48 hours between regenerations is customary.

The bauxite is regenerated by passing a mixture of air and steam into the catalyst bed at a temperature of about 750° F. The rate of carbon removal is determined by the rate of air addition and the maximum temperature rise from burning off the carbon is controlled by the concentration of the air in the air-steam mixture. The regeneration is normally carried on at a temperature of 1200-1400° F. Combustion gas can also be utilized as the diluent in the regeneration gas stream.

Blends of straight run and cracked naphthas may be desulfurized together. The principal advantage of adding the straight run stock is that of diluting the olefins and decreasing the rate of carbon deposition on the catalyst, thereby prolonging the length of operating periods between regenerations.

A further application of catalytic desulfurization is that of desulfurizing high sulfur straight run thermal reformer stock. The improvement in lead response thereby obtained permits reforming at somewhat less severe conditions so that for the same leaded octane ratings the yield of gasoline from the desulfurized naphtha is 2 to 4 percent higher than from the reforming of the undesulfurized naphtha.

Mild reforming of straight run and cracked naphthas over bauxite differs from desulfurization primarily in that the temperature level is raised to the region of 950-1050° F., the catalyst is usually regenerated every 24 hours and, in addition to the improvement in lead response, the clear octane rating of the naphthas is increased from 5-15 octane numbers with debutanized gasoline yields of 90 percent or more. Aside from decomposition of most of the organic sulfur compounds and some of the hydrocarbons, reactions taking place in the catalyst bed are complex. Dehydrogenation, cyclization and isomerization are known to occur. Unlike desulfurization, reforming over bauxite produces gas other than hydrogen sulfide but dut to the low operating pressure the C_3 and C_4 fractions are relatively rich in olefins and consequently can be recovered through the medium of polymerization of alkylation. Since some olefins are produced in the gasoline fraction, this mild catalytic reforming improves the Research as well as the ASTM octane number and so furnishes the refiner a tool for upgrading low octane stocks, even though the sulfur content is small.

In reforming straight run stocks over bauxite to debutanized gasoline yields of 85-90 percent, carbon deposition is of the order of 0.2-0.5 percent by weight of the charge; with cracked stocks carbon deposition is about doubled due to the higher carbon-forming properties of the olefinic constituents.

77 Hydrocarbons Separated From Petroleum by API

API Project No. 6, in preparation since 1927, has resulted in separation of 77 hydrocarbons from petroleum, Dr. Frederick D. Rossini of the Bureau of Standards said in his recent talk at Bradford, Penn. The cooperative project of the API and the Bureau has involved a total of 200 man-years and has resulted in making available 112 standard hydrocarbons used in the research, development and control laboratories for calibrating infra-red, ultra-red, daman and mass spectrometers.

New Type Lubricants and Fuel Needed by Military

Development of new types of fuels, lubricants and fuel and lubricant additives for use in extremely hot and extremely cold climates is No. 6 in a list of 25 major technical problems of the Army, Navy and Coast Guard issued last month by the National Inventors Council for solution by American inventors.

A general invitation to submit suggestions was extended by Charles F. Kettering, chairman of the council, and John C. Green, chief engineer, explained that any inventor with a suggestion may disclose it to the council without jeopardizing his patent rights.

The Army's "Task Force Frigid," which wintered in Alaska, demonstrated that the use of engineer equipment in areas of extreme temperatures presents new problems in the starting and operating of gasoline and diesel engines, and new types of fuel and lubricants are outstanding requirements, it was stated by the council in listing its problems.

An ideal Diesel fuel oil, it was said, would be one that would not appreciably lose its physical and chemical characteristics at -65° F., and there is need for lubricating oil which would maintain satisfactory viscosity and have a pour point of approximately -60°, while solid lubricants and gasoline which would remain usable at the lower temperatures also are needed.

Glidden Announces Licensing of Lecithin

The Glidden Company, Cleveland, has announced that it is now prepared to license firms in the petroleum industry for the use of the lecithin patents in the production of motor fuels and lubricating oils. The announcement follows the consent decree, which closed the American Lecithin Company case. Further the announcement from P. E. Sprague, vice president explains:

"This results from arrangements made by Glidden with the Texaco Development Corporation, the E. I. du Pont de Nemours & Company, the Socony-Vacuum Oil Company, and the American Lecithin Company, embracing the whole series of American and foreign patents owned by these concerns which grew out of the extensive research conducted on the use of lecithin as an additive agent to improve the quality and performance of lubricating oils and of gasoline motor fuels.

"Continued intensive developments in this field with Gliddol were largely held up by the war and can now be renewed by the petroleum industry and by the Glidden Company, which participated in the early research and whose patents also are included. There are some 18 to 20 patents involved and, according to Mr. Sprague, a number of the important American producers of lubricating oil and gasoline are utilizing these processes successfully."

Brochure for Chemists

A 1947 edition of the Foster D. Snell, Inc., brochure under the heading "The Chemical Consultant and Your Business," just off the press, is obtainable without charge from the company at 29 West 15 Street, New York 11. Included are problems which the chemical consultant encounters, types of business enterprises which find use for such services, the various branches of service offered, corporation policy in relation to clients, the basis of charges and the types of agreements which are offered.

Minerals Yearbook

The Minerals Yearbook for 1945, previously printed as separate chapters, is now available through the Government Printing Office, Washington, cost $4.00. Checks should be sent to the Superintendent of Documents.

The book, which has been returned to the postwar status, contains 1689 pages.

To a New Post

John Biegel, who has been a process engineer with Union Oil Company at its Wilmington plant, is now associated with Tarr & McComb Oil Company, Ltd., Los Angeles.

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Purification, Purity and Freezing Points of 7 Heptanes, 16 Octanes, 6 Pentenes, Cyclopentene, and 7 C_9H_{12} Alkylbenzenes of the API-Standard and API-NBS Series. ANTON J. STREIGG, EVELYN T. MURPHY, VINCENT A. SEDLACK, CHARLES B. WILLINGHAM AND FREDERICK D. ROSSINI *(Natl. Bur. of Standards, Washington, D. C.) J. Research Natl. Bur. Standards,* **37** (1946) pp. 331-78.

Work was done for the purpose of obtaining for each hydrocarbon one liter of API-Standard material of 99.8 mol-% purity to be used for standard samples and 0.2 l. of material of higher purity for API-NBS samples. The hydrocarbons were purified by regular and/or azeotropic distillation, using columns of 125-200 theoretical plates and reflux ratios of 110-290:1. The history of the purification of each hydrocarbon sample is tabulated. Distillation curves showing the boiling point at 724.5 mm., refractive index, freezing point and purity in mole-% plotted against vol. of distillate are given for each of the listed hydrocarbons. In the purification of the hydrocarbons, the following points were noted. First, simple purification in connection with preparation removes most impurities except close-boiling isomers. Second, several % of impurity of close-boiling isomer has relatively little effect on boiling point, but quite an effect on density and an appreciable effect on freezing point. And third, in a distillation the highest fraction of purity may be beyond or ahead of the middle portion as well as at the middle portion of the total distillate. And lastly, the freezing point is the only safe basis for choosing fractions of the highest purity.

Antoine Vapor-Pressure Equation. The Antoine Vapor-Pressure Equation for Mononuclear Aromatic Hydrocarbons. N. N. CORBIN, M. ALEXANDER, AND G. EGLOFF, *Universal Oil products Co., J. Phys. & Colloid Chem.* **51** (1947) pp. 528-40.

It was endeavored to determine whether the variation of the constants in the Antoine equation

$$\log p = A - \frac{B}{t \quad C}$$

with the number of carbon atoms could be used to predict vapor pressures and boiling points of compounds for which experimental data are inadequate. It was found that these properties can be predicted for the normal alkylbenzene series and the 2-methyl-2-phenylalkane series. For other types of alkylbenzenes the variations are too great. Constants A and B have been evaluated and related to the number of carbon atoms in several values of C. The relationship, A and B to C was evaluated for the normal alkylbenzene series. Vapor pressures at a variety of temperatures or at the boiling point at pressures between 10 mm. and 800 mm. can be estimated.

Vibrational Frequencies of Olefins. Normal Coordinate Analysis of the Vibrational Frequencies of Ethylene, Propylene, cis-2-Butene, Trans-2-Butene, and Isobutene. J. E. KILPATRICK AND K. S. PITZER, *J. Research, Natl. Bur. Standards.* **23** (1947) pp. 191-209.

Forces operating around an olefinic double bond were investigated, in order that reliable statistical thermodynamic calculations could be made. The number of internal degrees of freedom in the molecules of propylene, cis-2-butene trans-2-butene, and isobutene is so large that a complete vibrational assignment from spectral data alone is unreliable. The 1-butene molecule presents an even more difficult problem because of the complete lack of symmetry and the presence of an unbalanced rotation in the molecule. A satisfactory assignment is available, however, for ethylene. An expression was determined that would reproduce the vibrational frequencies of C_2H_4 and C_2D_4. These constants were used, either directly or with modifications, and with addition of potential constants from other molecules, to calculate the vibrational frequencies of propylene and the three rigid-frame butenes (cis- trans-, and iso). The complete vibrational frequency assignments are presented in tables. The description of the motion is only approximate. Complete matrix equations are given.

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The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal, and Dearborn Streets, Chicago 16, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the Registry.

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β,β-Diphenylacrylic acid
2,2-Dichlorocamphane
Phenyldimethylphosphine
Dialkylphosphines
Monoalkylphosphines
Phenylphosphine
Hexacosane
3-Carboxy-4-hydroxypyrazol
α-Chloroethylbenzene
Glyoxylic acid
1,4-Dihydronaphthalene
Bicyclo-2,2,1-heptane
2,6-Dimethoxy-4-propylphenol
Dihydromyrcene

The Entropy of Nitromethane. Heat Capacity of Solid and Liquid. Vapor Pressure, Heats of Fusion and Vaporization. W. M. JONES AND W. F. GIAUQUE, *Jour. Am. Chem. Soc.,* **69** (1947) pp. 983-7.

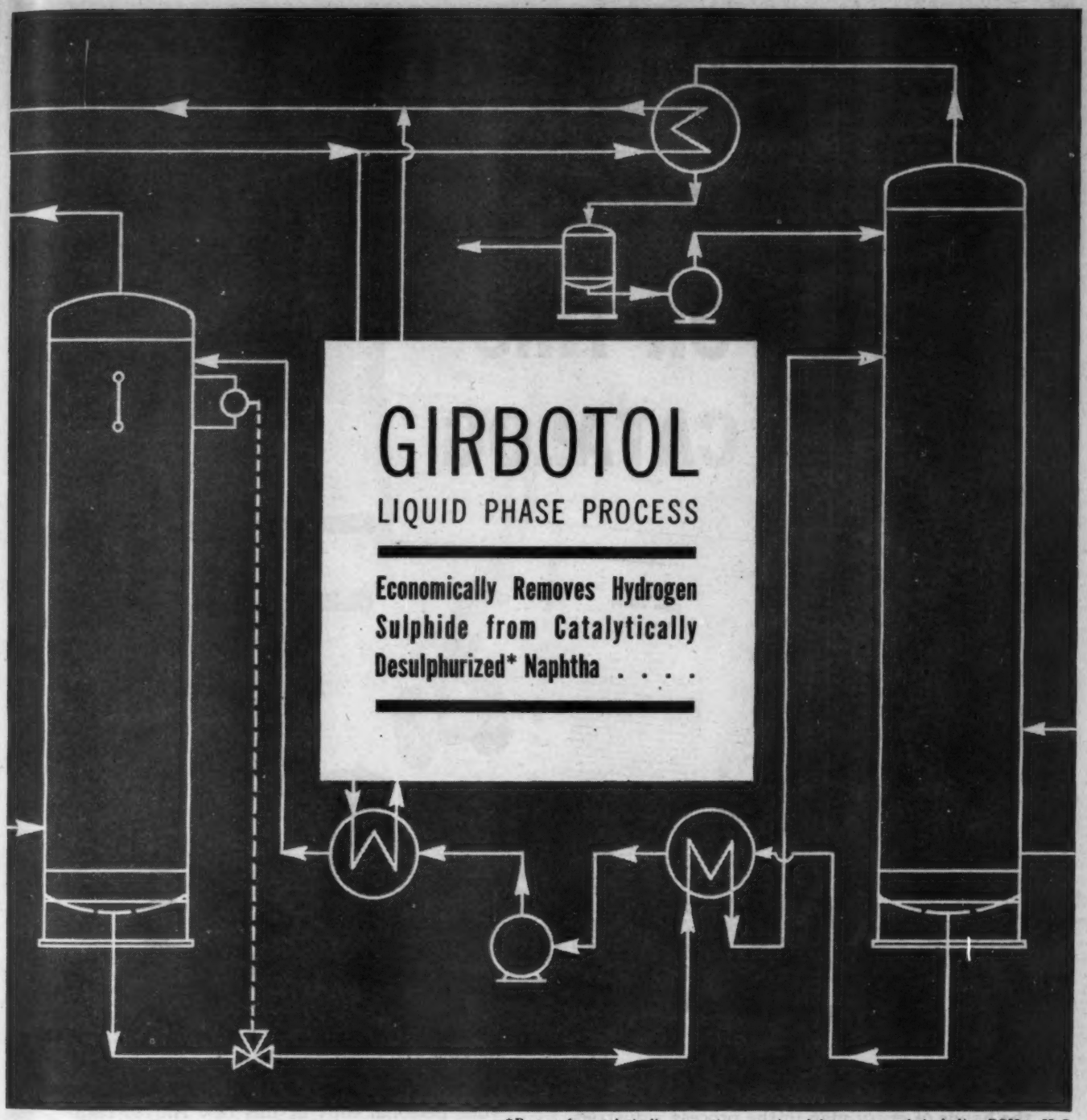
The heat capacity of solid and liquid nitromethane was determined from 13 to 300° K. the melting point was found to be 244.73° K. The heat of fusion is 2319 cal./mole. Vapor pressure at 25° C. was found to be 3.666 cm. and the heat of vaporization at this temperature as measured calorimetrically was 9147 cal./mole. The data were used to calculate the entropy of nitromethane in the ideal gas state at 298.1° K. and 1 atm. The value found was 65.73 cal./deg./mole. This value does not include the entropy of nuclear spin. The value of the entropy was combined with calculations based on available molecular data, and the six-fold potential barrier restricting internal rotation in the nitromethane molecule was found to be 500 cal./mole, which value is in good agreement with those found by Pitzer and Gwinn, and De Vries and Collins.

The Electrostatic Ignitibility of Various Solvent Vapour-Air Mixtures. A. R. BOYLE AND F. J. LLEWELLYN, *Jour. Soc. Chem. Ind.* **66** (1947) pp. 99-102.

The influence of discharge capacity, electrode shape and size, electrode material, temperature of the vapour-air mixture, and resistance in the discharge circuit, on the ignitibility of a number of solvent vapour-air mixtures was studied. Ignition occurs most easily, i.e. at a minimum energy, when the capacity is low; when the electrodes are not points a minimum voltage is necessary for ignition no matter what is the size of the capacitor, but with point electrodes the critical factor is the energy stored in the capacitor.

Fluorinated Derivatives of Propane. E. T. MCBEE, H. B. HASS, R. M. THOMAS, W. G. TOLAND, JR., AND A. TRUCHAN, *Jour. Am. Chem. Soc.,* **69** (1947) pp. 944-7.

The work described is an extension of the research undertaken for the purpose of synthesizing fluorine-containing



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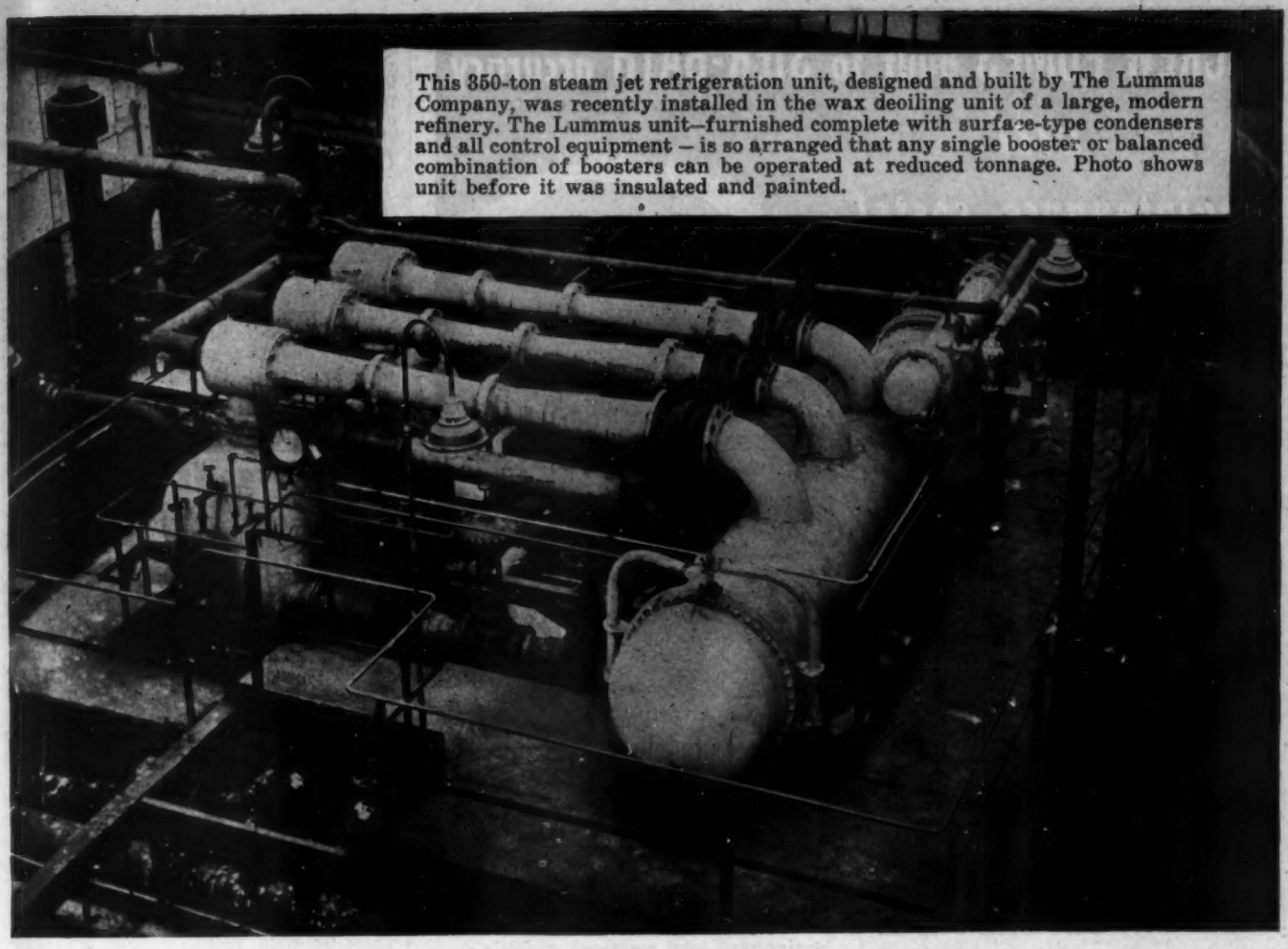

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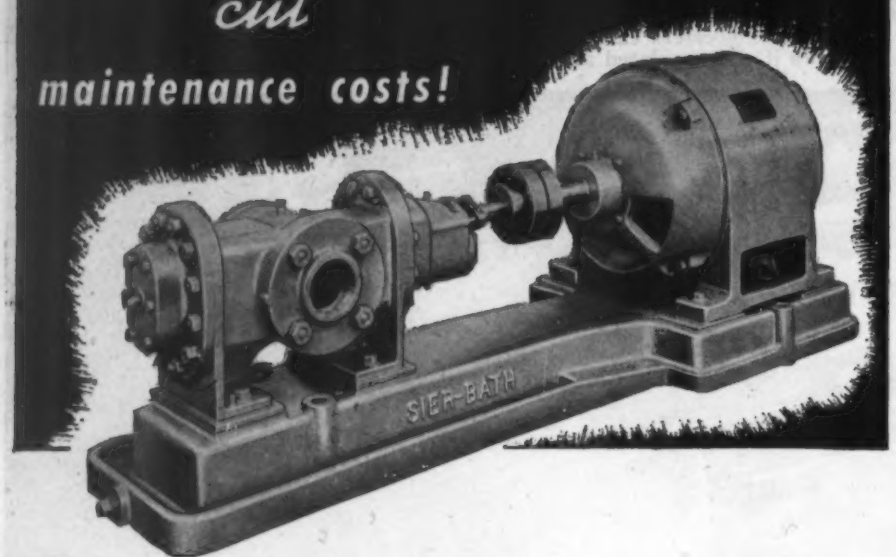

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compounds for pharmacological tests. Synthesis of certain fluoro derivatives of propane was described in a previous paper. The investigation has now been extended to include additional derivatives of propane. The preparation of $CF_3CH_2CH_3$ and $CClF_2CH_2CH_3$ was accomplished, and in excellent yields. Both photochemical and thermal chlorination of $CClF_2CH_2CH_3$ yielded several new chlorofluoropropanes. Several new fluorine-containing propanes were prepared by the fluorination of certain chloro- and chlorofluoropropenes with mercury oxide and hydrogen fluoride. Some bromofluoropropanes were also synthesized by fluorination of the corresponding bromides.

Chemical Compositions and Reactions

Explosive Decomposition of Ethene. H. I. WATERMAN, W. I. HESSELS, AND J. VAN STEENIS. *Jour. Inst. Petroleum*, 33 (1947) pp. 254-5.

The author reviews the literature bearing on the explosive decomposition of ethene when polymerized under pressure. It was found that some solvents for aluminum chloride have a promoting action on the polymerization of olefins. If, however, the starting pressure of ethene is about 40 atm. an explosion can result even at temperatures as low as 0° C. At a lower starting pressure, such as 20 atm., a vigorous reaction ensues, which, however, can be kept under control. In the presence of aluminum chloride with nickel, ethene was added up to 60 atm. pressure at 18° C. The temperature increased rapidly to 330° C. After this explosion a pressure of 450 atm. was recorded. The reaction residue consisted of a soft coal-like mass. In the presence of aluminum chloride and methylchloride at —20° C, ethene was introduced to 30 atm. pressure. At —5° C., brought about by slowly warming the autoclave, an instantaneous increase of pressure and temperature took place. The reaction product was a soft coal-like mass. Other similar experiments are described.

Certain Fundamental Concepts Relating to Non-Polar Mechanisms in Olefinic Systems. E. H. FARMER. *Jour. Soc. Chem. Ind.*, 66 (1947) pp. 86-93.

Extensive investigation of four important and superficially dissimilar types of reactivity that are observable with olefinic hydrocarbons has left little doubt as to the facility with which non-polar types of reaction can occur, and has revealed what appears to be a general rule governing non-polar additive reactivity—a rule distinct from, and indeed the counterpart of, that governing ionic or polar additivity. By application of this rule it is possible to formulate the purely additive lines of reaction that can occur between olefinic substances and appropriate reagents. The actual courses pursued are largely determined by dual factors of hydrogenlability and additive capacity on the part of the olefin and by the chemical character on the part of the reagent. The application of polar concepts to the interpretation and systematization of experimental observations in the field of organic chemistry has had such striking success and usefulness during the past 25 years that

these concepts have become an integral part of organized chemical knowledge. In recent years, however, there has been a steady accumulation of experimental results that do not fit into the polar scheme and this may be rationally and consistently interpreted as resulting from the occurrence of apolar type of reaction in which the participants are short-lived neutral entities (either molecules or atoms) displaying free-radical characteristics. In the apolar basis the author outlines a hypothetical correlation of a considerable array of experimental results with which he has been concerned—both as an immediate aid to making sense of what would otherwise seem to be unusually complicated and unintelligible, and with the hope that the views advanced will furnish suggestive starting points for future kinetic experimentation. A bibliography of 9 references is included.

Reactions of Atoms and Free Radicals in Solution. X. The Addition of Polyhalomethanes to Olefins. M. S. KHARASCH, ELWOOD V. JENSEN AND W. H. URRY, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1100-5.

In photochemical or peroxide-induced reactions with olefins containing terminal double bonds, carbon tetrachloride, carbon tetrabromide, chloroform and bromoform yield addition and polymerization-addition products. The reactions of carbon tetrachloride with octene-1, styrene, propylene, ethyl acrylate and biallyl, and of carbon tetrabromide with octene-1, styrene and ethylen, and of chloroform with octene-1 and biallyl, and bromoform with octene-1 and styrene were studied and are described. For all these halides, chain reactions can be induced by free radicals generated in the thermal decomposition of diacyl peroxides. Carbon tetrabromide takes part in chemical reactions under the influence of visible light; carbon tetrachloride requires the use of ultraviolet light. Reaction mechanisms are proposed, and the determined structures of the halide-olefin addition products are consistent with these mechanisms.

Reactions of Atoms and Free Radicals in Solution. XI. The Addition of Bromotrichloromethane to Olefins. M. S. KHARASCH, OTTO REINMUTH AND W. H. URRY, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1105-10.

In photochemical or peroxide-induced reactions with 1-alkene derivatives, bromotrichloromethane closely resembles carbon tetrabromide (rather than carbon tetrachloride) in its behavior. Under the conditions described, such reactions give good yields (such as 70-90%) of the 1:1 olefin-polyhalide addition products.

Condensation of Saturated Halides With Unsaturated Compounds. IV. Condensation of t-Butyl Chloride with Cyclohexene. LOUIS SCHMERLING, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1121-5.

Condensation of t-butyl chloride with cyclohexene in the presence of aluminum chloride at —25 to —15° C. gives a 72% yield of chlorobutylcyclohexane, about 85% of which compound is 1-chloro-3-t-butylcyclohexane, and the remainder is 1-chloro-t-butylcyclohexane. Use of bismuth chloride as a catalyst at 0° and at room temperature gives 5 and 21-25% yields, respectively, of similar mixtures of 1-chloro-3-t-butylcyclohexane with minor amounts of 1-chloro-1-t-butylcyclohexane. On the other hand, quite pure 1-chloro-1-t-butylcyclohexane in 23% yield is produced when boron fluoride is used at 0° C. t-Butylcyclohexene and chlorocyclohexane are by-products of the reaction in the presence of boron fluoride or bismuth chloride. The former is presumably produced by the dehydrochlorination of the chlorobutylcyclohexane, the hydrogen chloride adding to cyclohexene to yield the chlorocyclohexane. The proofs of structure of the two chlorobutylcyclohexanes are considered. Incidental to their identification, two new ketones, 2- and 4-t-butylcyclohexanone, were synthesized and characterized by means of the semicarbazone derivatives.

Manufacture: Process and Plant

Condensation and Subcooling Inside An Inclined Tube. J. B. TEPE AND A. C. MUELLER, *Chem. Eng. Progress*, **43** (1947) pp. 267-78.

An investigation was undertaken to determine the effects of angle of inclination, flow rate, and temperature difference on the rates of condensation of benzene vapor and methanol vapor and on the rates of subcooling of the liquid condensates inside a single water-cooled copper tube ⅞-inch in diameter and 3 feet long. Tests were made with the tube inclined at angles of 0°, 15°, and 90° to the horizontal. These showed that the condensation coefficients were affected only slightly by changing the angle of inclination. Condensate cooling coefficients decreased markedly as the angle of inclination was reduced. Condensation coefficients both for benzene and methanol increased with increasing vapor velocity at all inclinations. The effect was more marked for benzene than for methanol. Condensate cooling coefficients increased with increasing condensate flow rate at all inclinations. Effect was less marked as the angle of inclination decreased. Translated into terms of commercial vapor-in-tube condensate practice, the present results indicate that a condenser can be placed in any desired position without appreciable effect on the heat-transfer capacity, provided little or no subcooling of the condensate is required.

The Effect of Vapor Composition on the Assessment of Fractionating Columns in Terms of Heights of a Transfer Unit. Part II. J. ANDERSON STORROW, *Jour. Soc. Chem. Ind.*, **69** (1947) pp. 73-9.

Temperature measurements across the diameter of a wetted-wall fractionating column operating on ethanol-water mixtures indicated the form of vapour composition distribution across the column; the assumption being made that the temperatures measured were the condensation temperatures of the vapour. The results obtained illustrate the similarity between the processes of fractionation, uni-directional diffusion and heat transfer. In fractionation, H.T.U. obtained by thermocouple "sampling," and based on the mean vapour compositions are in close agreement with corresponding data obtained by sample-withdrawal methods. The data obtained are presented in graphical form and a bibliography of 18 reference is included.

Butane Isomerization. J. A. CHEMICEK, J. O. IVERSON, R. E. SUTHERLAND, AND P. C. WEINERT, *Chem. Eng. Progress*, **43** (1947) pp. 210-18.

The alkylation of all available light olefins for maximum production of aviation gasoline during wartime required the increased production of isobutane. The need for isobutane was met by the isomerization of normal butane by several different processes. The present article describes an isomerization process that has been developed which has several improved features, such as the deposition and maintenance of high activity catalyst on inert packing in the reactor by continuous introduction of aluminum chloride, and the recovery and recycling of the catalyst in the reactor effluent. The development of this process and the operation of this plant raised several engineering problems. Among these problems were the design of equipment for the fractionation of mixtures of aluminum chloride, hydrogen chloride, and hydrocarbons, selection of suitable pumps for handling solutions of aluminum chloride in hydrocarbons, combating corrosion in reaction vessels, and proper variation of the operating conditions in commercial plants to overcome difficulties caused by changes in overall refinery operation. The purpose of the present paper is to describe the process and discuss the problems encountered. Results obtained in commercial practice are presented. Future developments of the process will be directed more to improving the octane rating of straight-run fractions. The excellent yield of high octane product obtainable with this process makes it suitable for this purpose.

Analysis of Silica-Alumina Cracking Catalysts. R. A. BURDETT AND L. C. JONES, JR. *Anal. Chem.* **19** (1947) pp. 238-41.

The use of silica-alumina type cracking catalysts has become common in recent years. It has been necessary to analyze these catalysts for contaminants introduced in their manufacture and in their subsequent use in the cracking process. Most of the available analytical methods are time-consuming and in many instances are not of adequate sensitivity. Others involve difficult analytical techniques so that the results obtained by any but highly skilled technicians are subject to large errors. It was found by the authors that the application of the spectrographic method to the analysis of these catalysts gives a rapid procedure of adequate accuracy that is easily mastered by semi-skilled personnel. The spectrographic method was therefore developed for the determination of iron, sodium, vanadium, nickel, chromium and copper, in silica-alumina cracking catalysts. The procedure is rapid and correlates well with the conventional chemical analyses. About 30 minutes are required for the complete analysis when the sodium content of the catalyst is greater than 0.1%. Another 15 minutes may be necessary for catalysts of low sodium content because of the additional arcing necessary in such cases.

Fires in Open Tanks of Petroleum Products: Some Fundamental Aspects. J. H. BURGOYNE, AND L. L. KATAN, *Jour. Inst. Petroleum* **33** (1947) pp. 158-91.

Observations were made upon the behaviour of a representative selection of petroleum products when burned in open-topped cylindrical vessels. It has been shown that many refined oils burn

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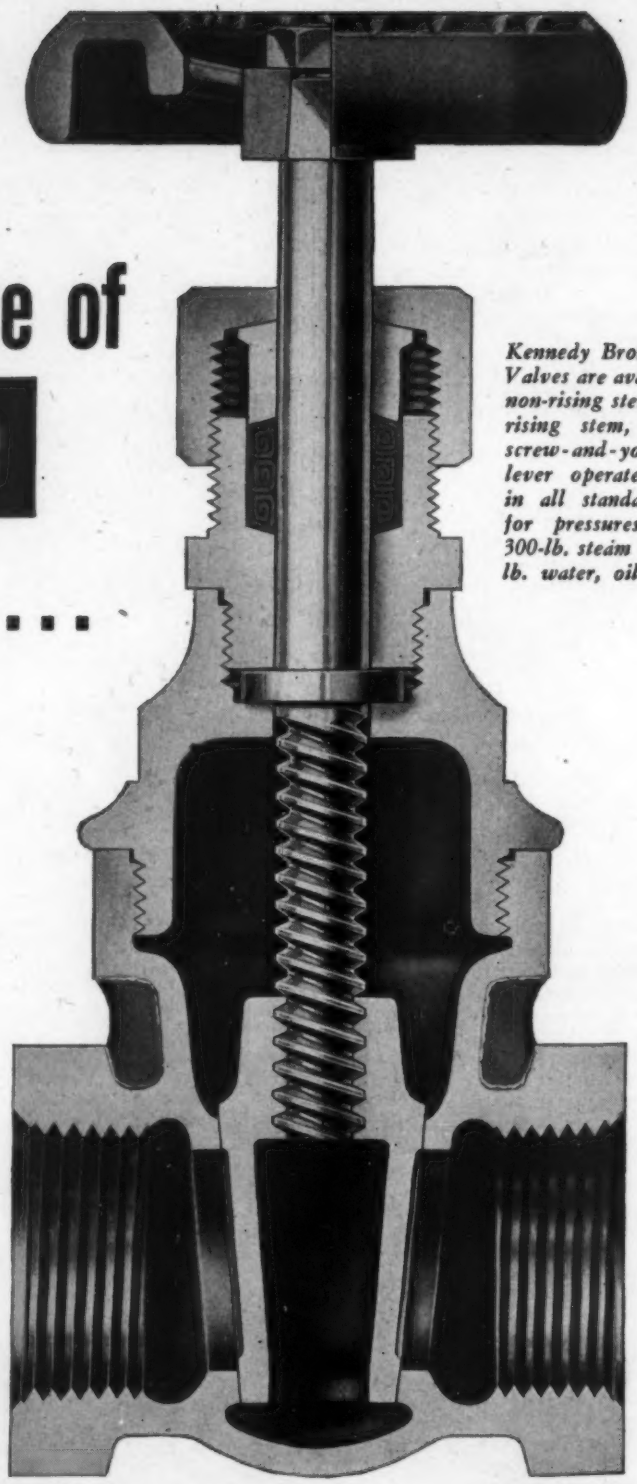

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in such a way that virtually all the fractions are removed layer by layer leaving little or no residue of any kind. The bulk of the oil, apart from a comparatively shallow layer, near the surface, is not affected at all by the fire. Crude and residual oils, and motor spirit have, however, been found to burn in such a way that only the lighter fractions are removed layer by layer and a hot residue steadily accumulates, floating on the unaffected oil. The hot residue, especially if its temperature exceeds 100° C (as it does with crude oils and fuel oils), constitutes a hazard particularly when extinction of the fire by the use of water in some form is attempted. It is suggested that in these circumstances the body of cold oil below may be used to cool the hot residue and thus remove the hazard. Some methods of doing this are considered, and it is shown that the method not only removes much of the danger but may be extended, within limitations that are defined, to the complete extinction of the fire without the use of auxiliary measures, both in oils that do and do not form the hot residue before burning.

Fires and Explosions at Oil Installations. E. P. LANCASHIRE, *Jour. Inst. Petroleum,* 33 (1947) pp. 131-58.

This article describes results of bombing of oil tanks and installation in Great Britain. The nature of the hits and the results are described for a series of attacks. It was found in general that the erection of walls either close to the tank side, or a few feet away was of great value in saving storage tanks from puncture. However, if the tanks become ignited the walls present a hazard because they prevent efficient cooling of the tank side-plates. The standard rate of application of foam used is one gallon of foam per square foot of area per minute. Speed is essential in dealing with the outbreak of fire involving petroleum products. Experiments both large and small proved the volume application of foam to be effective.

Experiments on the Rate of Foam Application to Petrol Fires. N. O. CLARK, E. THORNTON, AND J. A. LEWIS, *Jour. Inst. Petroleum,* 33 (1947) pp. 192-201.

A study was made during the past six years of the physico-chemical aspects of foam fire-fighting. This has resulted in some clarification of the relevant factors of importance in the properties of the foam. Among these are: the expansion factor or density; the specific surface of the foam, that is size of the bubbles; the stability of the foam at atmospheric and elevated temperature; the ease of spreading over the fuel surface; and the resistance of the foam to breakdown under the influence of the fuel by contact with the liquid or its vapor. The solution of the foaming agent may vary in the nature of the agent and in its concentration. Other factors that affect the efficiency of a foam installation are: design of the foam generating apparatus, conditions of water pressure, and the manner of application of foam to the fuel. Experimental methods used in the work are briefly described. It was found that for heated foam on a given fire there is a critical rate of delivery below which no progress toward extinction is made. The data indicate that the resistance of the foam to the fire is a function of water content.

Products: Properties, Utilization and Analytical

Petroleum Products in Agriculture: The Role of Petroleum in Plant Protection. L. W. LEYLAND COLE, *Jour. Inst. Petroleum,* 33 (April, 1947) pp. 203-18.

The large loss of food crops, due to weed competition and to the activity of insects and fungi in the field and in the warehouse, is being reduced by the development of new and more effective methods of protection. Petroleum oil has long been used in the form of oil-water emulsions for application to deciduous and to citrus fruits, and in recent years chemicals derived from petroleum have found applications in agricultural pest control. The base oils of horticultural sprays have certain accepted characteristics, but more work by the biochemist and plant physiologist is required before the perfect spray oil can be selected. In practice, dilute oil emulsions of various types are sprayed on the tree both in winter and in summer, care being taken to combine maximum insecticidal effect with minimum phytotoxicity. Oil is an excellent insecticide in itself but it is also an important carrier for other insecticides and for fungicides. Certain petroleum fractions possess weed-killing properties and are useful both as selective and non-selective herbicides. Important chemicals derived from petroleum and used in pest control are ester salts, methallyl chloride, and a mixture of dichloropropene and dichloropropane, the latter being a very successful soil fumigant. A bibliography of 11 references is included.

Short-Cut Methods of Infrared Analysis. W. D. SEYFRIED AND S. H. HASTINGS, *Anal. Chem.* 19 (1947) pp. 298-304.

In connection with plant and pilot-plant operations for the production of butadiene from butylenes, several short-cut infrared procedures were developed for the rapid, accurate determination of certain key components in samples containing other compounds, the measurements of which were not necessary and which can be readily determined by other means. Although some of the procedures are applicable only for specific purposes, others are general in nature and can be applied to a wide variety of samples. The procedures can be divided into three categories: base-line methods (for isobutylene and isobutane in mixture with other C_4 hydrocarbons); Procedures based upon measurements of optical density at uniform wave lengths as for methane, carbon monoxide, and carbon dioxide in mixture with hydrogen and small amounts of C_3 and lighter hydrocarbons; and comparison of standard techniques, as for butadiene—1,3 product purity and butadiene 1,2 in mixture with other C_4 hydrocarbons. Analyses of synthetic mixtures under routine operating conditions have demonstrated that these procedures are accurate to within a few tenths of 1% and that the time requirement is in the order of 15 to 20 minutes. Data obtained during investigations on abnormalities in absorption coefficients exhibited by various compounds showed that, of the paraffin, mono-olefin, acetylene, and allene series, the abnormality was most pronounced for the first member of each series and that it decreased as the molecular weight increased. A bibliography of 17 references is included.

The Oxygen Boost Method of Rating the Engine Performance of Aviation Fuels. W. B. HEATON, T. K. HANSON, AND R. C. MORRIS, *Jour. Inst. Petroleum,* 33 (1947) pp. 256-65.

The authors discuss the methods of knock rating of aviation fuels. A combined research project was launched on the development of a supercharged laboratory engine, the rich-mixture ratings of which would correlate with those of the single-cylinder Bristol Pegasus engine. As an alternative to supercharging the C.F.R. engine with compressed air the proposal to use oxygen directly from a cylinder appeared attractive. Rich-mixture response curves could then be obtained by plotting the rate of flow, limited by knock, of the added oxygen against the rate of fuel flow. Modifications made of a standard Motor Method C.F.R. engine are listed. The test procedure used is described and typical data are presented in tabular and graphical form.

Application of Infrared Spectroscopy to the Analysis of Liquid Hydrocarbons. J. J. HEIGL, M. F. BELL AND J. W. WHITE, *Anal. Chem.* 19 (1947) pp. 293-8.

The application of infrared spectroscopy to the analysis of hydrocarbon solutions is described in detail. Emphasis is placed on accuracy, rapidity, and simplicity of the so-called "base-line" technique that uses spectra superimposed on the radiant energy background. An analysis of the octane fraction illustrates development of the procedure. The method can be applied to a wide variety of samples. The method is based on the proportionality between concentration and absorption peak height above a spectrum reference line. These "base-line" optical density measurements are applied in preference to optical density measurements utilizing a reference cell determination, because of advantages in speed of spectrum scanning, calibration, and calculation. The analysis of the typical gasoline sample is effected by first separating the sample into fractions containing four to eight components, by means of a precision distillation column. Analysis of the fractions involves (a) proper blending of cuts of similar composition, (b) qualitative determination of the compounds present by inspection of the complete spectrum, (c) measurements of the base-line optical densities at the selected wave-length intervals, (d) substitution of these values in the appropriate equations, and (e) solution of the equations and calculation to obtain the final results. The instrumentation needed to handle the work is described. A bibliography of 16 references is included.

Would Extend Compact

A four-year extension of the Interstate Oil Compact Commission, recommended by President Truman "in view of the necessity for the conservation of our resources of oil and gas" is provided for in measures introduced in the Senate by Carl A. Hatch of New Mexico and in the House by Representative Glen D. Johnson of Oklahoma.

The compact, originally started in 1935, now has a membership of 16 states.

Digest of Recently Issued United States

Patents Pertaining to Petroleum Refining

Compiled by HEINZ HEINEMANN

REFINING

U.S.P. 2,418,814. Method for Determining Iso-Paraffins in Hydrocarbon Mixtures. G. W. Ayers and E. E. Harton, Jr., to The Pure Oil Company.

The amount of hydrocarbons having a C atom with a single H atom linked thereto in a hydrocarbon mixture is determined by reacting this mixture with $SbCl_5$ in the presence of an uranyl salt, such as uranyl nitrate, capable of catalyzing the reaction at a temperature below that at which clorination of normal paraffin hydrocarbons occurs. The resulting mixture is titrated with alkali metal bromate solution. The Moldavskii method for determining the iso-hydrocarbon or the tertiary hydrocarbon content of a hydrocarbon mixture is improved by reacting the mixture in the presence of an uranyl salt.

U.S.P. 2,418,988. Removal of Muck from Wash Oil. D. K. Segur to Donner-Hanna Coke Corp.

Wash oil which has been employed in scrubbing gases to recover light oils and which has assimilated in this use polymerizable adulterants of the nature of styrene, indene and cyclopentadiene is mixed with caustic soda. The mixture is heated for at least several hours and agitated during a portion of the heating period. The adulterants polymerized by this treatment are separated from the wash oil.

U.S.P. 2,419,039. Extractive Distillation of Hydrocarbons with Furfural-water Mixtures. V. Scarth to Phillips Petroleum Co.

Unsaturated hydrocarbons are recovered from admixture with less saturated hydrocarbons by extractive distillation with furfural containing dissolved water, as selective solvent. Water is volatilized in this process and passes overhead together with hydrocarbons from furfural absorbing and furfural stripping steps. The total overhead from each of these steps is condensed and separated into two layers, viz. a hydrocarbon layer and an aqueous layer containing corrosive impurities, while a portion of stripped furfural is withdrawn from the furfural stripping step and is steam distilled to remove polymers and other impurities therefrom prior to returning the furfural to the furfural absorption step. The corrosive impurities are eliminated by withdrawing the aqueous layer containing them and using them as the source of steam for steam distilling the stripped furfural. The loss of water and furfural from the system is thus decreased.

U.S.P. 2,419,247. Recovery of Hemimellitene. S. F. Birch and R. A. Lowry to Anglo-Iranian Oil Co., Ltd.

Hemimellitene (1,2,3-trimethylbenzene) (b.p. 176.1°C) is recovered from a narrow boiling range hydrocarbon oil fraction of petroleum or coal-tar boiling between 175° and 180° C. which besides hemimellitene contains a small proportion of pseudocumene (1,2,4-trimethylbenzene) (b.p. 169.3°C.) and a proportion of hydrindene (b.p. 178.3°C.) or another aromatic hydrocarbon with a b.p. close to that of hemimellitene. The hemimellitene is converted by catalytic hydrogenation of the narrow boiling fraction into 1,2,3-trimethylcyclohexane (b.p. 142°C.), the pseudocumene into 1,2,4-trimethylcyclohexane (b.p. 140-143° C.) and the hydrindene into cis-and trans-bicyclononanes (b.p. 166° and 159° C., respectively), or into the corresponding other saturated cyclohexane derivatives. By fractionately distilling the hydrogenated mixture an intermediate fraction boiling between 140 and 145° C. is recovered which contains only the trimethylhexanes. This fraction is catalytically dehydrogenated to reconvert the cyclohexanes into the original aromatic hydrocarbons. The dehydrogenated product contains only hemimellitene and pseudocumene readily separable by fractional distillation. A nickel-tungsten sulfide hydrogenation catalyst can be used for S-containing feeds and a Raney nickel catalyst for S-free feeds, while a molybdenum oxide catalyst on alumina can be used in the dehydrogenation step.

U.S.P. 2,419,335. Purification of Butadiene by Extractive Distillation with Nitroparaffin Solvents. D. Craig to The B. F. Goodrich Co.

Butadiene is recovered from a mixture of C_4-hydrocarbons with substantially the same b.p. by contacting the mixture in the gaseous state with a liquid nitroparaffin of the formula $R\text{-}NO_2$ wherein R is an alkyl group with less than 6 C atoms, e.g. nitropropane, and recovering enriched butadiene from the nitroparaffin. Contacting of the mixture with nitroparaffin can be effected by distilling the mixture in an efficient fractionating column down which flows a stream of the liquid nitroparaffin which serves as a selective solvent for butadiene.

U.S.P. 2,419,350. Butadiene Desorption Method. R. A. Given to Standard Oil Development Co.

An ammoniacal cuprous acetate solution containing butadiene, as obtained in the recovery of butadiene from a mixture of hydrocarbons, is passed into a first desorbing zone and desorbed butadiene is withdrawn from this zone. The remaining solution is removed from this zone and heated to a temperature higher than that of the first zone. The heated solution is introduced into a second desorbing zone. Desorbed vapors comprising butadiene and ammonia are passed from this zone countercurrent to the solution in the first zone. The solution withdrawn from the second zone is further heated to a temperature higher than that of the first heating and introduced into a third desorbing zone. The desorbed vapors of butadiene and ammonia from this third zone are passed countercurrent to the solution in the second zone. The solution withdrawn from the third zone is substantially free of butadiene. Temperatures employed can be: about 80° F. in the first zone, 140° F. in the second zone, and 180° F. in the third zone.

U.S.P. 2,419,499. Solvent Extraction of Unsaturated Materials. J. C. D. Oosterhout and T. C. Reddy, Jr., to The Texas Co.

An olefinic hydrocarbon mixture containing mono-olefins and di-olefins is extracted with furfural at elevated temperatures, e.g. at 140-340° F., in the presence of a small amount of a compound with at least one phenylamino group, such as a N-phenyl substituted thiourea, guanidine or naphthylamine. This compound is used in an amount sufficient to inhibit polymer formation. A solvent phase is formed which contains dissolved olefins, and a hydrocarbon phase which comprises relatively insoluble hydrocarbons. These phases are separated and the solvent is removed from the hydrocarbons. Butadiene can, for example, be extracted from a C_4 hydrocarbon mixture of the indicated kind with furfural in the presence of 0.1-0.2 percent by weight of the furfural, of N,N^1-diphenyl thiourea.

U.S.P. 2,419,579. Apparatus for Re-Refining Lubricating Oil. M. J. Livingston.

The apparatus serves for the purification of lubricating oil by contact filtration and is particularly useful in the re-refining of used lubricating oil of petroleum origin. The apparatus comprises a treating chamber with sealable oil inlet, an air and steam inlet to the bottom of the chamber, and a vapor outlet from the chamber connected with a condenser by means of a valve. An oil transfer tube passes through an upper portion of the wall of the chamber and terminates at the lower point of this chamber. A pipe provided with a valve connects the transfer tube with an oil receiving chamber. A separate air pressure line is connected with the receiver which has a vapor outlet connected by means of a valve with the condenser. The condenser is connected with a vacuum generator. A liquid discharge line provided with a filter is connected to the receiving chamber.

U.S.P. 2,419,521. Process for Recovery of Aromatic Hydrocarbons. J. W. Waldron to Allied Chemical and Dye Corp.

A nitration grade aromatic hydrocarbon, such as toluene, is recovered by fractional distillation of an oil which also contains higher, lower, and like-boiling non-aromatic hydrocarbons including like-boiling olefins. An oil fraction with an end point not more than 1.06 times the b.p. in degrees centigrade of the aromatic hydrocarbon and containing this hydrocarbon and olefins in

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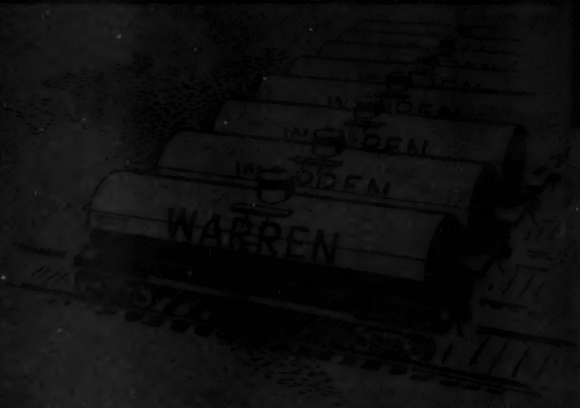

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an amount such that the numerical value of the ratio percent aromatics: bromine number for this oil fraction of less than 250 is taken off. This fraction is azeotropically distilled in the presence of a material forming low-boiling azeotropes with the non-aromatic hydrocarbons present. All of the like-boiling and lower boiling non-aromatic hydrocarbons other than olefins and a portion of the olefins are taken off with the azeotrope former as an overhead distillate. The aromatic hydrocarbon fraction recovered in this azeotropic fractional distillation contains the aromatics and a portion only of the olefins. This fraction is washed with H_2SO_4 of a concentration and in an amount such that the fraction is completely freed of olefins. The washed aromatics are freed from reaction products of the H_2SO_4 and olefins neutralized with alkali and then fractionally distilled. A fraction of nitration grade aromatic hydrocarbon is collected separate from forerunnings and a higher boiling residue. An aliphatic monohydroxy alcohol, such as methanol, or a ketone and water, can be used as the azeotrope former.

U.S.P. 2,420,185. Process for Producing Asphaltic Materials. H. E. Messmore to Phillips Petroleum Company.

A crude oil stock containing asphaltic and non-asphaltic materials is countercurrently contacted with a continuous stream of natural gas at a pressure of 9,000-10,000 psi and at a temperature of about 120° F. The non-asphaltic materials are vaporized into the natural gas while the asphalt with natural gas dissolved therein remains in liquid phase. The natural gas is separated from the admixture with the non-asphaltic materials in the gaseous phase and recycled to the original contacting step. The pressure on the liquid asphaltic phase is reduced to release at least a portion of the dissolved natural gas. The pressure is then further reduced to below 1000 psi to release a further quantity of the dissolved natural gas, while a blending naphtha is simultaneously added. Finally the pressure is reduced to atmospheric to release the remaining dissolved natural gas. The natural gas first separated from the liquid asphaltic phase is compressed to 9,000-10,000 psi and then recycled to the original contacting step. A blended asphaltic oil is obtained.

U.S.P. 2,419,755. Chemical Treatment of Oil Sands. F. W. Albaugh to Union Oil Company.

Water-wet oil sands are contacted with a hydrocarbon oil solution of an organic heterocyclic polycyclic amine, such as quinoline or its homologs, which does not substantially affect the water-oil interfacial tension. The permeability of the wet oil sand to oil is increased by this treatment. The solution can be forced through a well into the oil sands immediately surrounding the well. After subsequent withdrawal of the solution from the well, it can immediately produce oil.

U.S.P. 2,420,108. Process for Treating a Solvent-Extracted Petroleum Distillate with Clay and Lime. R. K. Stratford and O. S. Pokorny to Standard Oil Development Company.

A phenol-extracted petroleum distillate of the gasoil to light lubricating oil boiling range, or of the turbine oil, hydraulic oil and transformer oil viscosity range, and with a ratio of paraffinic to naphthenic constituents greater than 2:1, is treated with activated clay in the presence of lime at a temperature of 350-500° F. A stabilized refined oil of improved resistance to oxidation and emulsification is obtained. About 4-7% by weight of clay and 0.75-1.25% of hydrated lime can, for example, be employed.

U.S.P. 2,420,122. Suppression of Metal Catalysts. J. A. Chenicek to Universal Oil Products Company.

The deterioration of hydrocarbon distillate boiling in the gasoline range in the presence of a metal normally active to catalyze this deterioration is inhibited by the addition of a small amount of a compound of the general formula: Y - CO - CHX - CX′ = N - R - N = CX′ - CHX - CO - Y where Y is OH, OR′, NH_2, NHR′, or NR'_2; R′ is an alkyl or aryl group, X and X′ are hydrogen or alkyl groups, and R is an alkylene or arylene group, and the nitrogen atoms of the compound are attached to different C atoms of R, Bis- (beta-imino N-phenyl carboxylic or butyric acid amide, or 2,3-butylene-bis-(beta-imino butyric acid amide) can, for example, be used for this purpose in an amount of 0.001-0.05%.

CATALYST PREPARATION, ACTIVATION, AND REGENERATION

U.S.P. 2,418,888. Dehydrogenation Catalysts. K. K. Kearby to Standard Oil Development Company.

The dehydrogenation catalyst according to this patent consists of 50-97 parts by weight of ZnO, 3-50 parts of Fe_2O_3 or MnO, or Cr_2O_3, 0.5-15 parts of an alkali metal oxide promoter and 1-15 parts of a stabilizer preserving the activity of the promoter and selected from the oxides of the metals of the right hand side of group I of the periodic system, e.g., CuO.

U.S.P. 2,419,272. Process for Forming a Silica-Containing Hydrogel. M. M. Marisic and A. C. Schmitt to Socony-Vacuum Oil Company, Inc.

An alcoholic solution of an alkyl silicate is acidified to a pH between about 0 and 1 and thereafter neutralized to a pH of 4-9 by addition of a dilute aqueous solution of ammonia. The neutralized solution can be injected into a body of a water-immiscible liquid as a plurality of globules and retained in this condition in the liquid until the globules gel to firm hydrogel globules. The hydrogel is formed from the neutralized hydrosol within 30 seconds.

U.S.P. 2,419,342. Catalysts for Hydrocarbon Conversion. K. C. Edison and F. E. Fisher to Skelly Oil Company.

This catalyst consists of about 84% by weight of a carrier, such as Al_2O_3, about 8% of chromium oxide, or vanadium oxide, or molybdenum oxide, and about 8% of BaO_2. The activity of the catalyst for aromatizing aliphatic hydrocarbons is greatly enhanced by the presence of BaO_2.

U.S.P. 2,419,343. Process of Preparing Catalysts. K. C. Edison and F. E. Fisher to Skelly Oil Company.

A catalyst of the type indicated in U.S.P. 2,419,342 is prepared by impregnating a carrier with an aqueous solution of a compound of Cr, Mo, or Vd and drying to remove water. The compos-

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tion obtained is wetted with a non-aqueous non-ionizing organic liquid, such as acetone or hydrocarbon halide, and then mixed with an oxide of Ba. The mixture is heated to volatilize the organic liquid and further heated in an oxidizing atmosphere to decompose the first mentioned compound under formation of the corresponding oxide and to convert the oxide of Ba to BaO_2.

U.S.P. 2,419,504. Boron Fluoride Recovery Process. W. A. Schulze and W. N. Axe to Phillips Petroleum Company.

BF_3 is recovered from its admixture with normally gaseous hydrocarbons as obtained in catalytic processes, by contacting the mixture in the gaseous state with an absorption medium consisting essentially of liquid anhydrous HF. Selective absorption of the BF_3 is thereby effected. The enriched absorbent is separated and the BF_3 is stripped from the HF by heating the enriched absorbent.

U.S.P. 2,419,558. Recovery of Hydrogen Fluoride Catalyst. J. D. Gibson to Phillips Petroleum Company.

Hydrocarbon material containing organic fluorine compounds is contacted with a porous metal oxide defluorinating agent under such defluorination conditions that the fluorine is removed from the hydrocarbon material and retained by the agent. This agent is then treated with superheated steam at a temperature above 600° F. to convert retained fluorine to HF and to remove the HF formed from the agent. The HF is absorbed from the resulting vaporous mixture with a fluoride of alkali or earth alkali metal at a temperature not higher than 400° F. and under such conditions that no liquid aqueous phase is present and the partial pressure of the HF is substantially greater in the resulting vaporous mixture than in the metal fluoride. The HF is then desorbed from the metal fluoride. Dehydrated bauxite can be used as the defluorinating agent.

U.S.P. 2,416,807. Lubricant. F. M. Watkins to Sinclair Refining Company.

The lubricant consists principally of a petroleum lubricating oil fraction and contains in solution 0.05-1 percent by weight of the reaction product of stearonitrile and P_2S_5, P_2S_3, or P_4S_7. Octyl salicylate can be added up to an amount of a 2-10 times the weight of said reaction product. The characteristics of the lubricating oil especially with respect to oxidation and corrosion properties are improved by the addition of said reaction product. The salicylate added serves as a detergent.

U.S.P. 2,418,889. Dehydrogenation Catalyst. K. K. Kearby to Standard Oil Development Company.

The dehydrogenation catalyst according to this patent consists of 50-97 parts by weight of BeO, 3-50 parts of Fe_2O_3, and 0.5-15 parts of K_2O.

U.S.P. 2,419,245. Regenerating Carbon Contaminated Catalysts. M. H. Arveson to Standard Oil Company of Indiana.

Spent catalyst contaminated with carbonaceous matter is introduced into the upper end of an elongated regeneration zone inclined from the horizontal and passed over and under a succession of vertical baffles within this zone. A succession of short vertical columns of aerated dense phase catalyst is maintained between the baffles. An oxygen-containing regeneration gas is introduced at the bottom of the catalyst columns for aeration and regenration of the catalyst by combustion of the carbonaceous matter. The admission of oxygen-containing gas to the catalyst is controlled to avoid overheating the catalyst by too rapid regeneration. The regeneration gases are discharged from the space above the catalyst in the columns, and regenerated catalyst is withdrawn from the lower end of the inclined regeneration zone.

CRACKING AND REFORMING

U.S.P. 2,418,879. Pyrolysis of Hydrocarbons to Produce Olefins. J. H. Haslam to The Girdler Corporation.

In order to reduce the deposition of carbon on an alkaline earth oxide catalyst during pyrolysis of a hydrocarbon to form an olefin, or to form butadiene from cyclohexane, the catalyst is preheated for more than an hour to a temperature above that at which pyrolysis is to be effected but not above 1300° C., e.g., to 650-1300° C. The hydrocarbon to be treated is then passed over the catalyst at the pyrolysis temperature, e.g., at 100-650° C.

U.S.P. 2,418,993. Process for Making Improved Gasoline. W. J. Sweeney to Standard Oil Development Company.

Gasoline of high octane number and a low degree of unsaturation is continuously produced by adding a powdered cracking catalyst to the vapors of a gas-oil to form a suspension of catalyst in the vapors, and passing this suspension through a first cracking zone at a temperature of 800-950° F. The catalyst is separated from the cracked products and regenerated. The products are fractionated to recover a gasoline fraction. The regenerated catalyst is added to this gasoline fraction. The suspension of catalyst in the vapors of this fraction is passed through a second cracking zone at a temperature of up to 850° F. The catalyst is then separated from the products removed from this zone, and mixed without regeneration with the gasoil fed to the first cracking zone as the sole cracking catalyst used therein.

U.S.P. 2,419,097. Process for Catalytically Reacting Gaseous Material. C. W. Stratford and D. H. Putney to Stratford Development Corporation.

This process is somewhat similar to that of U.S.P. 2,419,088. The gaseous reactant is passed in contact and concurrently with the solid catalyst moving as a cyclic ring in the reaction zone and including separated upflowing and downflowing catalyst columns. The contact of the reactant with the catalyst is principally effected in the upflowing column. This column is subjected to rotative energy applied at spaced intervals to accelerate the lineal flow of catalyst in the ring and turbulence in the upflowing column. Catalyst and reacted materials are separated after contact in the upflowing column.

U.S.P. 2,419,098. Contacting Gases and Vapors with Cyclically Moving Catalyst. C. W. Stratford, J. A. Altshuler, and D. H. Putney to Stratford Development Corporation.

This process is similar to those of U.S.P. 2,419,088 and 2,419,097. The mechanical rotative energy is imparted to the cyclic streams of catalyst and reactant mixtures in the reaction and regeneration steps independent of the energy supplied to the feed of the material to the respective steps.

U.S.P. 2,419,088. Process for Contacting Reactants with Catalytic Material. D. H. Putney to Stratford Development Corporation.

In a procedure of catalytic circulation and separation for processes of treating gaseous materials rings of moving catalyst are established in both the reactor and the catalyst regenerator. These rings have concentric upflowing and downflowing columns. Reactant gases are contacted with the catalyst ring in the reactor and regenerating gases with the catalyst ring in the regenerator. Turbulence and propelling force is mechanically imparted at spaced intervals to the gas catalyst mixture along the upflowing column. The mixtures of catalyst and gases are subjected in the respective steps to gravitational separation. The streams of separated gases containing entrained catalyst are passed upwardly in secondary separation zones. Centrifugal force is mechanically imparted to these upwardly flowing streams to separate entrained catalyst from them and project it to the peripheries of the secondary separation zones. The separated catalyst is returned to the catalyst rings. The procedure has particular application to fluid catalyst cracking processes for the production of motor fuels from petroleum hydrocarbons.

U.S.P. 2,419,427. Manufacture of Gasoline Using Adsorptive Calatlysts. J. W. Teter to Sinclair Refining Company.

A finely divided adsorptive catalyst is mixed with high-boiling petroleum oil to be cracked. The mixture is passed at a velocity adequate to maintain the catalyst in intimate admixture with the oil through a cracking zone maintained at a cracking temperature upwards of 900° F. The mixture is kept in this zone under the conditions described for a period of time sufficient to produce a substantial yield of gasoline in a single pass. The discharged mixture is then separated into a composite gas-vapor mixture and a residual component comprising spent catalyst. The gas-vapor mixture is fractionated to separate therefrom a first high-boiling condensate and an intermediate condensate having a boiling range higher than that of gasoline but lower than that of said first condensate. The remaining gas-vapor mixture is subjected to a condensing operation and a stabilizing operation to separate therefrom a stabilized gasoline and a fraction comprising normally gaseous hydrocarbons. The latter are contacted with an absorbent oil. The thus enriched absorbent oil and at least a portion of the first mentioned high-boiling condensate are supplied to the cracking zone. At least a portion of the intermediate condensate is discharged from the system without reintroduction to the cracking zone. A high anti-knock gasoline is obtained by the process.

U.S.P. 2,419,507. Method of Catalytic Conversion. T. P. Simpson, J. W. Payne, and J. A. Crowley to Socony-Vacuum Oil Company, Inc.

Fluid petroleum hydrocarbons are converted into high quality gasoline by cycling catalyst in a closed circuit including a conversion zone and a revivification zone and introducing vapors of the fluid hydrocarbons into a moving

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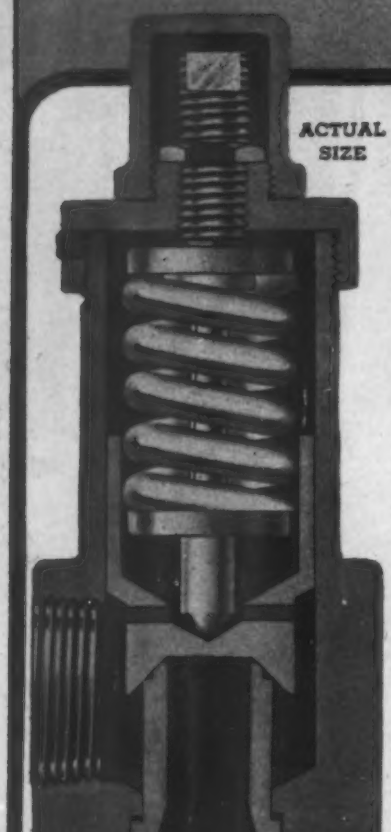

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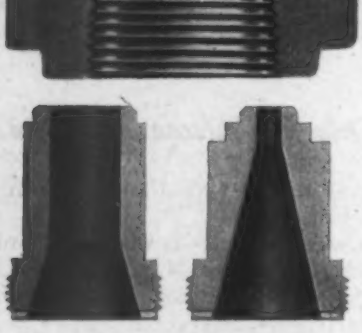

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compact column of the catalyst within the conversion zone. The catalyst is removed from this zone without appreciable entrainment of hydrocarbon vapors and is continuously conducted to the revivification zone where it is regenerated at high temperature. It is then returned to the conversion zone while excluding combustion-supporting gases from entering the zone. The products of the conversion step are recovered separately.

U.S.P. 2,419,508. Apparatus for Catalytic Conversion. Th. P. Simpson, J. W. Payne, and J. A. Crowley to Socony-Vacuum Oil Company, Inc.

The apparatus for continuous catalytic cracking of hydrocarbon oil comprises a pipe still for heating the oils to cracking temperature, a cracking chamber with inlet and outlet for the catalyst and inlet and outlet for the charging stock and the product, respectively. A transfer line connects the charging stock inlet with the pipe still. The product outlet of the cracking chamber is connected with a fractionating system. A revivification chamber with inlets and outlets for the catalyst and for the revivification medium, respectively, is connected directly with the catalyst outlet of the cracking chamber to transfer hot spent catalyst from this chamber directly to the revivification chamber, while the cracking and the revivification operations are in progress. A valve is located between the catalyst outlet of the cracking chamber and the catalyst inlet of the revivification chamber, said valve being adapted to transfer catalyst while preventing substantial flow of gas therethrough: Another valve is located at the catalyst outlet of the revivification chamber adapted to transfer hot revivified catalyst from the latter chamber to the cracking chamber during the operations while preventing substantial flow of gas through this valve. Both the transferring means for the catalyst from the cracking chamber to the revivification chamber and vice versa can be provided with a chamber having an inlet and an outlet, each, for the passage of an inert fluid or gas for purging the catalyst and preventing the escape of reactant gas from the cracking chamber. This apparatus is to be used in the process described in U. S. patent 2,419,507.

U.S.P. 2,420,145. Process for Conversion of Hydrocarbons at High Cracking Temperatures. J. McAfee to Universal Oil Products Company.

A mass of subdivided solid contact material is continuously circulated between and through a confined reaction zone, a confined combustion zone, and a confined steam superheating zone in series. Hydrocarbons are converted at high cracking temperature and low pressure in the reaction zone in contact with the subdivided solid material passing therethrough. The combustible contaminants deposited on the contact material are burnt in the combustion zone with oxidizing gas. The highly heated contact material is passed through the steam-superheating zone where it is contacted with steam which is thus heated to the temperature desired for conducting the hydrocarbon conversion reaction. The resulting highly heated steam is passed through the reaction zone in admixture with the hydrocarbons. Valuable normally gaseous hydrocarbons, including butadiene, are obtained by the process.

U.S.P. 2,420,030. Motor Fuels and Preparation Thereof. R. C. Brandon to Standard Oil Development Company.

A petroleum hydrocarbon stock composed of hydrocarbons with at least 5 C atoms is subjected to vapor phase cracking under conditions to produce large quantities of cyclopentadiene with other unsaturated C_5 to C_8 hydrocarbons boiling below 110° and above 127° F. The cracked products are fractionated to separate therefrom a fraction boiling within the approximate limits of 90-145° F. This fraction is hydrogenated and the hydrogenated product is again fractionated to separate therefrom a fraction consisting essentially of n-pentane. The other components of this product which essentially include isopentane, cyclopentane and branched hexanes are combined to obtain a motor fuel blending agent having the desired combination of antiknock and vapor pressure properties and being especially useful in leaded fuels for supercharged aviation engines to be used under rich mixture operation for maximum power output.

ISOMERIZATION

U.S.P. 2,419,423. Isomerization of Normal Pariffin Hydrocarbons. E. E. Sensel, H. V. Atwell, and A. R. Goldsby to The Texas Company.

A hydrocarbon feed of n-paraffin hydrocarbons is continuously passed in liquid phase to a primary contact zone and subjected there to intimate contact with active metal halide including metal halide-hydrocarbon complex at a temperature of 150-275° F. The feed is then passed from the primary zone to a secondary zone arranged at an elevation above the primary zone and subjected there to intimate contact with relatively fresh metal halide in solid form at said conversion temperature. The treated hydrocarbons and the complex formed are removed from the secondary zone, and the complex is passed by gravity flow to the primary zone for contact with fresh feed.

U.S.P. 2,419,667. Process for the Isomerization of Normal Paraffins. T. J. Williams to Universal Oil Products Company.

Pariffin hydrocarbons commingled with a hydrogen halide promoter are passed under isomerization conditions through a series of reaction zones containing metal halide catalyst of increasing activity in the direction of flow. The concentration of hydrogen halide promoter is decreased in the same direction by commingling an additional portion of the paraffinic hydrocarbons with the admixed reaction products and hydrogen halide passing from a zone of lower catalyst activity to a zone of higher activity.

U.S.P. 2,420,086. Isomerizing Paraffins and Naphthenes in a Mixed Feed. S. H. McAllister and C. C. Crawford to Shell Development Company.

A mixture of normally liquid saturated hydrocarbons boiling in the gasoline boiling range and comprising straight chain paraffins with at least 7 C atoms, such as n-heptane, and naphthenes of non-hydroaromatic structure and the same number of C atoms as the paraffins, such as dimethylcyclopentane, is contacted in a first conversion zone at a temperature below 80° C. in the presence of a hydrogen halide promoter added in an amount below 0.5% by weight of the charge, with a partially spent isomerization catalyst comprising an Al halide-containing mixture of molten salts obtained within the system. Naphthenes of non-hydroaromatic structure are converted to naphthenes of hydroaromatic structure, such as methylcyclohexane. These naphthenes are separated from the effluent of the first conversion zone. The remaining hydrocarbons are contacted with fresh isomeriaztion catalyst of the same type at a temperature of 85-125° C. in the presence of an added hydrogen halide promoter in a second conversion zone, thereby converting the remaining hydrocarbons to a high octane paraffinic hydrocarbon fraction comprising branched chain paraffins. Partially spent catalyst from the second zone is passed to the first conversion zone.

ALKYLATION

U.S.P. 2,419,599. Alkylation of Aromatic Hydrocarbons. W. A. Schulze to Phillips Petroleum Company.

A monoalkyl derivative of an alkylatable aromatic hydrocarbon, e.g., a monoalkyl benzene the alkyl group of which contains 2-6 C atoms, is obtained by passing a hydrocarbon mixture which comprises an olefin of not more than 6 C atoms and a molar excess of an alkylatable aromatic hydrocarbon, such as benzene, through a bed of a granular catalyst under conditions of temperature and pressure such as to promote union of the olefin and the aromatic to form a corresponding monoalkyl derivative thereof, e.g., at a temperature of 200-450° F. The catalyst comprises silica and 0.1-2% by weight of alumina and is prepared by passing an aqueous alkali silicate into an excess of an aqueous mineral acid and allowing the mixture to set to a silicic acid gel which is washed with water and only partially dried to form a hydrous acidic silica gel. This gel is then contacted with an aqueous solution of a hydrolyzable Al salt at a temperature approximating the b.p. of this solution. The activated gel thus obtained is washed with water to remove free acid and salts and finally dried to form hard granules. Each of these drying temperatures shall not be higher than the subsequent reaction temperature.

U.S.P. 2,419,632. Alkylation of Cyclic Hydrocarbons. R. B. Day to Universal Oil Products Company.

An alkylatable cyclic hydrocarbon, such as benzene, and an alkylating agent, such as ethylene, are alkylated by means of a catalyst which comprises an $AlCl_3$-hydrocarbon complex formed by the interaction of $AlCl_3$ and an aliphatic olefin and has an $AlCl_3$ concentration above 60 but below 85% by weight of the complex. This catalyst has an unusually high activity and selectivity for the desired reaction.

U.S.P. 2,419,692. Alkylation. B. H. Shoemaker and B. L. Evering to Standard Oil Company of Indiana.

A mixture of isoparaffinic and olefinic hydrocarbons is contacted within a first contacting zone with a mineral acid alkylation catalyst, such as H_2SO_4, at a temperature of 40-60° F. The reaction mixture obtained is mixed in a second contacting zone with 0.1-1.5% of benzene or another alkylatable aromatic, based upon the volume of total hydrocarbons supplied to this second zone, and then treated in this zone at a temperature

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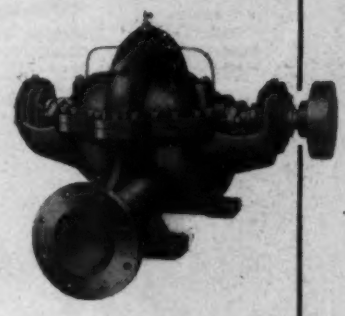

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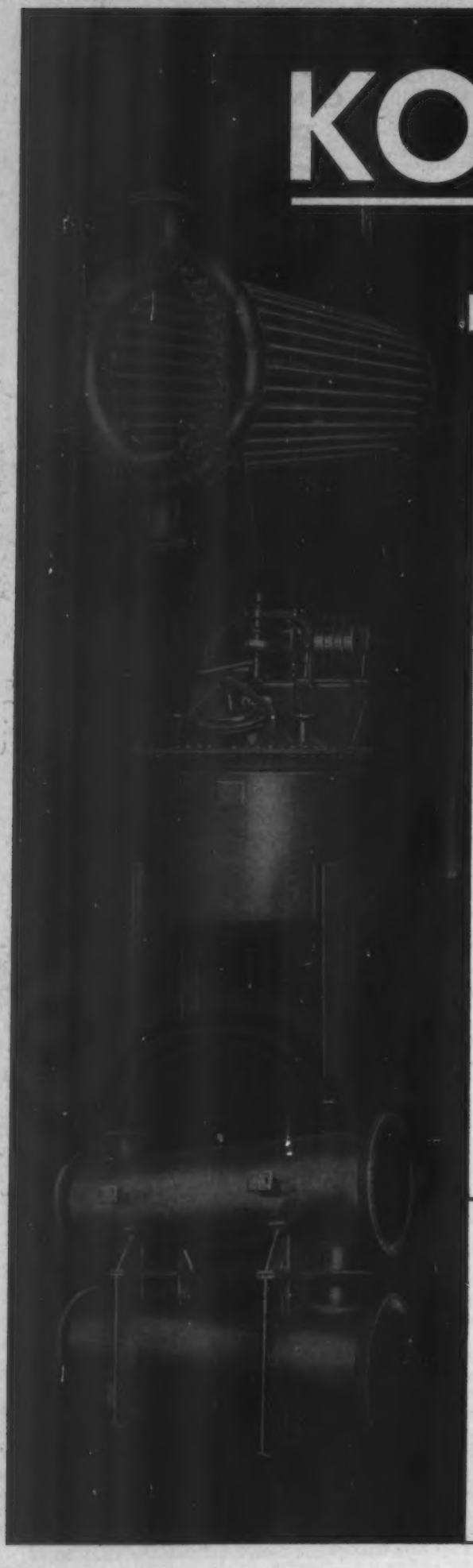

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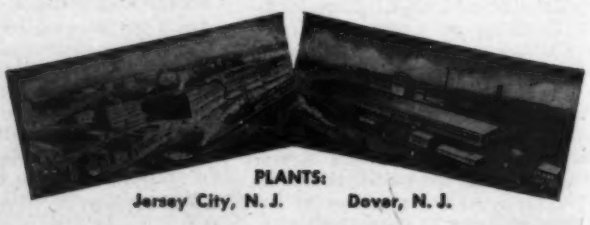

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substantially above that employed in the first zone. The benzene inhibits the normal tendency of the alkylation catalyst to disproportionate the alkylation product at the higher treating temperature. Hydrocarbons boiling within a narrow range are obtained.

U.S.P. 2,419,796. Alkylation Process. W. A. Schulze to Phillips Petroleum Company.

A hydrocarbon mixture comprising ethylene and a molar excess of an alkylatable aromatic hydrocarbon, such as benzene, is passed through a bed of a granular catalyst under alkylation conditions such that a corresponding monoethyl derivative of the aromatic is formed as the principal reaction. The catalyst used comprises silica and 0.1-2% of an oxide of a metal of groups IIIB and IVA of the periodic table, such as alumina. This catalyst is prepared by introducing an aqueous solution of an alkali silicate into an excess of a mineral acid and allowing the resultant mixture to set for the formation of a silic acid gel which is washed with water and only partially dried to form a hydrous acidic silica gel. This gel is contacted with an aqueous solution of a hydrolyzable salt of one of the previously mentioned metals, such as aluminum sulfate, to activate the gel by absorption of a hydrous oxide of this metal. The resultant material is washed and dried to form the granular catalyst. Both drying temperatures for the gel shall not be higher than the subsequent reaction temperature.

U.S.P. 2,420,073. Process of Partial Dealkylation. F. E. Frey to Phillips Petroleum Company.

A polyalkylbenzene is treated in admixture with a molecular excess of benzene or alkylbenzenes with at least 2 alkyl groups fewer than the polyalkylbenzene to be converted, and in the presence of HF under conditions to produce an alkyl derivative of benzene with fewer alkyl groups than the charge stock. The HF used can be previously utilized as a catalyst in the alkylation of benzene with olefins and contain alkyl fluorides. In this case the alkyl fluorides contained in the catalyst are converted to alkyl benzenes. The alkyl derivative of benzene thus produced, e.g., a monoalkylbenzene, such as toluene, is recovered from the process effluent.

POLYMERIZATION AND CONVERSION

U.S.P. 2,419,517. Conversion of Hydrocarbons. S. C. Eastwood to Socony-Vacuum Oil Company, Inc.

A particle-form catalyst is circulated in the form of a compact column in a closed cyclic path through an enclosed conversion zone and an enclosed regenerating zone. A heavy high boiling hydrocarbon oil containing a fraction boiling above the desired reaction temperature is heated to a temperature not higher than this reaction temperature and is charged in the heated state into said column at a point intermediate its ends. Vaporous portions of the charge oil move upwardly through the upper portion of the catalyst column, and the vaporous products of this conversion step are then removed from the upper end of the column. Liquid portions of the charge move downwardly through the lower portion of the catalyst column. Vaporous products of this second conversion step are removed from a point adjacent the bottom of the column. Contaminated catalyst is removed from the bottom of the conversion zone while preventing escape of vaporous hydrocarbon material with the catalyst. The contaminated catalyst is regenerated at high temperature and the regenerated catalyst is re-introduced in the heated condition into the conversion zone while preventing the escape of combustion gases into this zone. The heat of the catalyst and the temperature of the charge oil are proportioned so that the conversion zone is maintained at a reaction temperature of 800-1000° F. A high quality gasoline is obtained.

U.S.P. 2,418,857. Process for Performing Catalytic Vapor Phase Reactions. C. W. Stratford, J. A. Altshuler, and D. H. Putney to Stratford Development Corporation.

A cyclic flow of gaseous reactants and solid catalyst is maintained in the reaction step and includes upflowing and downflowing columns which have a common axis. A mechanical rotative energy is imparted in the upper portion of the upflowing column to accelerate lineal flow of the reactants and catalyst in separate columns. The process can be used for the reconditioning of solid catalytic material and it can be employed in any catalytic process wherein the reactants are in the vapor phase, such as in the cracking, hydrogenation, dehydrogenation, isomerization, polymerization, aromatization, and desulfurization of hydrocarbons.

U.S.P. 2,418,899. Process for the Synthesis of Hydrocarbons. E. F. Pevere, G. B. Hatch, and E. E. Sensel to The Texas Company.

A feed of CO, H_2 and isoparaffin hydrocarbon with 4-6 C atoms is continuously passed to a reaction zone and contacted in the gas phase with a synthesis catalyst comprising a metal of the VIIIth group of the periodic system at a temperature of 325-700° F. and under a pressure ranging from atmospheric to about 100 atmospheres. A stream of reaction products comprising unreacted isoparaffin and synthesized hydrocarbons is continuously removed from the reaction zone. The isoparaffin is separated from the reaction products and recycled to the reaction zone. The amount of isoparaffin entering the reaction zone shall be at least 5 mol % based on the CO in the reaction mixture. Isobutane or isopentane can, for example, be employed in the process. Motor fuels of improved anti-knock characteristics are obtained by this process.

U.S.P. 2,419,519. Conversion of Hydrocarbons. L. P. Evans to Socony-Vacuum Oil Company, Inc.

The process of this patent is similar to that of U.S. Patent 2,419,517. The heavy charge oil shall contain a fraction boiling above 840° F. It is first separated after heating into a vapor portion and a liquid portion. The vapors are introduced into the catalyst column at a point adjacent its upper end while the liquid portion is introduced into the column at a point intermediate its ends. Vaporous conversion products are removed from the column at a point below the point of liquid feed introduction and adjacent the lower end of the column. The treatment of the contaminated catalyst removed from the bottom of the conversion zone and the conditions of the re-introduction of the regenerated catalyst into the conversion zone correspond to those of U.S. Patent 2,419,517.

U.S.P. 2,419,528. Catalytic Conversion Apparatus. J. Biegel to Phillips Petroleum Company.

The apparatus comprises a catalytic converter and a fractionating column connected with the outlet of the converter. A plurality of feed inlets is arranged at different selective levels in the column. The valves in the inlet and outlet lines of the converter and the inlets of the column are automatically operated by common timing means. One of the feed inlet valves is selectively held open thereby to maintain overhead and bottom product streams of constant composition from the fractionator.

U.S.P. 2,419,668. Process for Preparing a Methylcylopentene Dimer. A. E. Bearse and J. E. Leonard to Standard Oil Company of Indiana.

A methylcyclopentene is polymerized by means of a H_2SO_4 catalyst. The methylcyclopentene polymers formed are fractionated to separate a dimer fraction boiling in the range of 214-6° C. at 749 mm. of mercury. An extraction of polymers formed by strong phosphoric acid can precede the fractionation. H_2SO_4 of 35-100 percent concentration is preferably employed in the polymerization at a temperature of 0-150° C.

U.S.P. 2,419,690. Conversion of Hydrocarbons. H. Pines and V. N. Ipatieff to Universal Oil Products Company.

A non-aromatic unsaturated cyclic compound with at least 8 C atoms, such as limonene, pinene, or a cyclic terpene, is treated at a temperature of 100-450° C. in the presence of a hydrogen halide by means of a catalyst consisting essentially of at least one of the refractory oxides of Al, Th, Si, Zr, or Ti. A polyalkylated aromatic compound is obtained e.g. tetramethylated benzene and alkylated cyclohexane from limonene.

U.S.P. 2,420,049. Catalytic Hydrocarbon Conversion Starting Up Procedure. H. Z. Martin to Standard Oil Development Company.

In the starting-up of an oil conversion process the powdered catalyst reactor and regenerators are first preheated, while empty, to a temperature of about 300° F. by introducing external hot gases. An amount of catalyst substantially less than the amount normally used in the process is then charged to the regenerator. The regenerator is further heated to at least 600° F. by continued introduction of hot gases. The heated catalyst is then passed to the reactor. Catalyst is again added to the regenerator and the heating is continued by the combustion of fuel, e.g. added combustible oil, in the regenerator until the catalyst in the regenerator is at a temperature of about 950-1000° F. Feed oil is thereafter introduced into the reactor to begin with the normal operation.

U.S.P. 2,420,129. Controlling the Flow of Fluidized Solids and Liquids. B. J. Flock and C. G. Gerhold to Universal Oil Products Co.

In a process wherein beds of subdivided solid material, particularly of a solid catalyst material, are maintained in a fluidized state in separate confined zones by the passage of a gaseous medium upwardly through these zones

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and wherein a confined stream of the solid material is directed from the bed in each zone through a restriction and into the other zone, a constant pressure drop is maintained through these restrictions to maintain a constant rate of circulation for the solid material between the two zones. The constant pressure drop is effected by measuring the pressure head in each of the zones at a point adjacent to and on the upstream side of the restrictions, and by controlling the gas outlet pressure in one of the two zones in response to variations in the relative pressures prevailing in the separate zones at said points.

HYDROGENATION DEHYDROGENATION AROMATIZATION

U.S.P. 2,418,890. Stripping of Spent Catalyst Particles in the Catalytic Conversion of Hydrocarbons. R. W. Krebs to Standard Oil Development Company.

Oil to be converted is passed upwardly in vapor form through a reaction zone containing a layer of finely divided conversion catalyst at a velocity controlled to maintain the layer in a dense turbulent condition. A stream of catalyst is continuously introduced into the reaction zone. Another stream of catalyst is downwardly withdrawn from the catalyst layer into a stripping zone where the catalyst is contacted with a stream of hydrocarbon vapors of a b.p. not lower than the b.p. of the feed. Valuable reaction products entrained in the catalyst are thus removed from the catalyst. The stripping hydrocarbons can be the same as the feed hydrocarbons, and their vapors can be passed from the stripping zone to the reaction zone. The process is, for example, useful in the dehydrogenation of hydrocarbons, such as butanes.

U.S.P. 2,419,323. Conversion of Hydrocarbon Oils. R. N. Meinert and P. H. Holt, 2nd, to Standard Oil Development Company.

Naphthas are continuously hydroformed to produce aromatics or aromatics-containing products by maintaining a Cr_2O_3 or Mo_2O_3 catalyst on spinel in powdered form in contact with the vapors of the reactants in which the catalyst is suspended in the form of a dense, fluidized, turbulent mass. A pressure of 15-50 p.s.i. is maintained in the reaction zone at reforming temperature. A quantity of catalyst is continuously withdrawn from the reaction zone for regeneration. Prior to this regeneration volatile hydrocarbons are removed from the catalyst in a stripping zone by causing the catalyst to flow countercurrently against a current of gas containing hydrogen. Catalyst withdrawn from this stripping zone is discharged into a second stripping zone where it is treated with steam to dislodge hydrogen and thus to prepare the catalyst for regeneration.

U.S.P. 2,419,997. Catalytic Dehydrogenation of Aliphatic Hydrocarbons. E. J. Houdry to Houdry Process Corporation.

The dehydrogenation of aliphatic hydrocarbons in a cyclic operation of onstream and regeneration of the catalyst is effected while maintaining the catalyst within the desired temperature range without use of extraneous heat exchange under such conditions of temperature and time of contact that burning of the carbonaceous deposit stores within the catalyst a portion only of the endothermic heat required during dehydrogenation. The balance of the endothermic heat is supplied by admitting reactants to the catalyst at a temperature above the average of the desired range of catalyst temperatures. The catalyst employed is an active oxide of Cr, Mo, or V supported by a carrier of capillary structure free of silica. This catalyst has been subjected in the absence of carbonaceous deposits to steam treatment at 1200-1600° F. at a partial steam pressure above 1 p.s.i. and above $\frac{400}{T\text{-}1160} - 1$ and below 30 p.s.i. and $\frac{475}{T\text{-}1630} + 32$, (where T equals treating temperatures in F.) for a sufficient period of time to permanently reduce the coke forming characteristics of the catalyst.

U.S.P. 2,420,143. Process for the Manufacture of a Polycyclic Hydrocarbon. W. J. Mattox to Universal Oil Products Company.

A secondary butyl benzene is subjected to the action of a dehydrocyclization catalyst comprising a compound of an element from the left-hand columns of groups V and VI of the periodic table, such as V, Ta, Cr, Mo, W. Dehydrocyclization can, for example, be effected at a temperature of 450-700° C. and under a pressure within the range of atmospheric to about 1000 p.s.i. Polycyclic hydrocarbons, such as naphthalene, phenanthrene, and the like are obtained.

DESULFURIZATION

U.S.P. 2,418,884. Process for Purifying Hydrocarbon Oils. C. O. Hoover to Air Reduction Company, Inc.

Sour hydrocarbon oil is passed in the presence of an oxidizing agent and a mineral acid successively through a turbulent zone and a superposed quiescent zone. Each of these zones consists of a slurry of solid particles comprising a mixture of an adsorbent material and a copper compound suspended in the hydrocarbon oil. The compound of copper is one which forms mercaptides with mercaptan, e.g. copper chloride.

U.S.P. 2,419,029. Process for Desulfurizing and Reforming Hydrocarbons. G. G. Oberfell to Phillips Petroleum Company.

A first motor fuel of relatively low antiknock value and lead susceptibility and containing sulfur in substantially non-refractory form is contacted with a reforming catalyst under such conditions that substantially no cracking takes place but hydrogen is produced and desulfurization occurs (e.g. at a temperature of 900-1200° F.). A second motor fuel consisting of cracked distillate containing refractory sulfur compounds and unsaturates is contacted with hydrogen at elevated temperatures and pressures but below reforming temperatures in a separate step to effect hydrogenation and pre-treatment of the refractory sulfur compounds. The hydrogenation and pre-treated cracked distillate is introduced into the reforming step to eliminate the sulfur compounds, whereby the cracked distillate and the first motor fuel are blended. The improved blended motor fuel thus obtained is withdrawn.

U.S.P. 2,420,218. Sweetening Hydrocarbon Oils. G. W. Ayers to The Pure Oil Company.

Sulfur compounds are removed from hydrocarbon oils by contacting these oils with an aqueous solution of alkali metal hydroxides or carbonates in the presence of a comminuted alloy of Cu or Ni and Si, Be, Al, or Zn. A temperature of about 38° C. can be used in the process.

HEAVY OILS AND WAXES

U.S.P. 2,418,894. Compounded Lubricating Oil. J. G. McNab and D. T. Rogers to Standard Oil Development Company.

A mineral lubricating oil base is compounded with at least a corrosion-inhibiting amount of a reaction product of 0.02-3 atomic proportions of elemental S with one mole proportion of a metal salt of a sulfonic acid, such as an alkaline earth metal salt of an alkylated phenol sulfonic acid or of petroleum sulfonic acids.

U.S.P. 2,419,153. Lubricant and the Like. J. M. Musselman and H. P. Lankelma to the Standard Oil Company of Ohio.

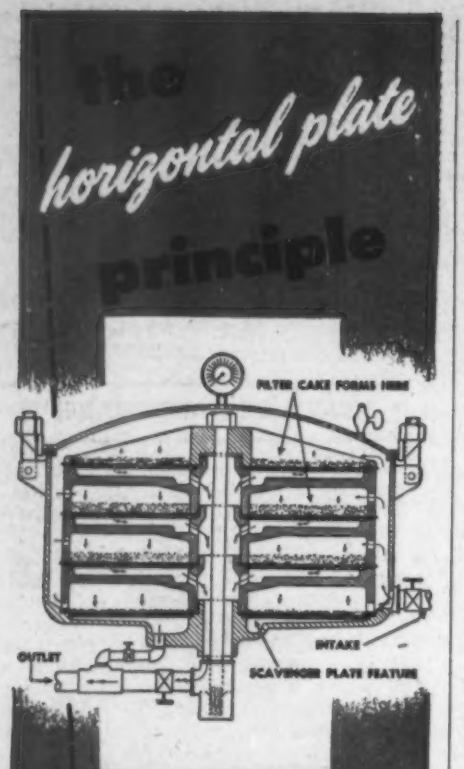
The lubricant comprises the product of reaction of an unpolymerized organic oxygen-containing compound forming oil-soluble metal phosphorus sulfide reaction products and having a b.p. not less than 300° F. with P_2S_5 at a temperature above phosphate formation and converted in turn into a metal compound. This reaction product can either be employed as such, for instance in gear lubrication, or it may be incorporated into an oil of lubricating viscosity, e.g. in oils of 40-3000 viscosity Saybolt Universal at 100° F. in amounts of, for example, 0.05-10 percent. These lubricants have greater stability and resistance against change and greater film strength than the usual petroleum lubricants.

U.S.P. 2,419,253. Lubricant. L. D. Cahill to Jack & Heintz Precision Industries, Inc.

The lubricant is to be interposed between friction clutch surfaces and consists of a mixture of a grease base and an impalpable solid scarifying agent finely divided in the grease, such as levigated alumina. This agent makes minute grease-retaining scratches on the lubricated surface so that the lubricant will not be completely squeezed out or rubbed off this surface by the imposition of frictionals loads thereon. About 1 part of the agent can be used on 200 parts of grease.

U.S.P. 2,419,325. Lubricating Composition. J. M. Musselman to the Standard Oil Company of Ohio.

A major portion of a lubricating oil is compound with a stabilizing quantity of an additive which comprises the metal compound of the reaction product of an oxygenated petroleum hydrocarbon boiling above the reaction temperature employed in the preparation of the product, and an amount of 14-30 percent of P_2S_5 at least stoichiometrically sufficient to supplant the oxygen of the oxygenated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. . . makes these the "filters that filter all liquids"—

SPARKLER
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FILTERS

. . . and here's the story:

- Sparkler Horizontal Plate Filters handle any liquid from heavy varnishes to light alcohols, including products such as acids, oils, beverages, milk, pharmaceuticals, plating solutions, water, etc.
- Equally efficient performance on intermittent or continuous operation, under a wide range of temperature, pressure and viscosity conditions.
- Equally effective whether removing carbons and contact clays or clarifying and polishing with filter aids.
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- Unexcelled filter cake stability—no slipping or breaking.

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Because filter media are supported on a horizontal plane and filter aids floated into position uniformly, filtration takes place uniformly over entire filtering areas. Flow through filter is always *with* gravity.

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MUNDELEIN, ILLINOIS

hydrocarbon with S. The reaction is effected at a temperature of 275-425° F. The reaction product formed is separated from a sludge comprising the major part of the phosphorous in the P_2S_5. The separated reaction product is converted into the metal compound, e.g. an alkaline earth compound, before it is added to the lubricating oil. While the lubricant has the advantage of increased oiliness caused by the addition of oxidized petroleum acids to lubricating oils it lacks the drawback of accelerated breakdown of the oil usually connected with such an addition.

U.S.P. 2,419,360. Lubricating Oil Composition. J. G. McNab, C. J. Wilson, and C. Winning to Standard Oil Development Company.

The lubricant comprises an oil base, a small quantity of an organic compound of the formula ROM where R is an aliphatic or aromatic radical free from carboxyl and metal substituted carboxyl groups, M is a basic acting unit, and the oxygen is attached to a C atom which is attached to C,H or N; and a small quantity of a product obtained by reacting p-cresol with a reagent which furnishes a tertiary alkyl group, in the presence of an alkylation catalyst. The first named additive serves to impart detergent properties to the lubricant while the second named additive serves to offset the corrosiveness of the first. Calcium octodecylate or the barium salt of cashew nut shell phenol can, for example, be used as the first additive, and the reaction product of p-cresol with isobutene in the presence of a catalytic amount of H_2SO_4 as the second additive.

U.S.P. 2,419,584. Mineral Oil Composition. T. T. Noland to Socony-Vacuum Oil Company, Inc.

The invention has to do with the stabilization of viscous mineral oil fractions against oxidation and deterioration. For this purpose the mineral oil contains 0.1-3.0 percent of a stable, oil-soluble, P and S containing reaction product obtained by reaction of P_2S_5 and a hydrocarbon stock at a temperature of 125-200° C. for relatively short reaction time. The hydrocarbon stock employed in this reaction is characterized by an olefin content of 3-7 percent and an aromatic content of 40-60 percent. The P_2S_5 is employed in an amount of 1-8 percent by weight of the hydrocarbon stock. The type of reaction product obtained normally tends to form a haze in the oil. This haze formation is suppressed by addition to the mineral oil combination of 0.001-0.3 percent of an oil-miscible metal salt of a sulfonic acid.

U.S.P. 2,419,586. Mineral Oil Composition. F. P. Otto and R. E. Meyer to Socony-Vacuum Oil Company, Inc.

The mineral oil composition, which is particularly suitable for use as a lubricant, dielectric oil and the like, comprises a viscous mineral oil fraction mixed with a minor proportion of a non-corrosive, sulfurized aliphatic ketone obtained by sulfurizing an unsaturated aliphatic ketone with elementary S at elevated temperature. The ketone employed has at least one olefin group separated from the keto group by at least one C atom. Ketones of the general formula: R-CH=CH-R'-CO-R" or R-CH=CH-R'-CO-R'-CH=CH-R, wherein R is H or an aliphatic group and R' and R" are aliphatic groups, can be used, such as dioleyl ketone. The oil is stabilized by the addition.

U.S.P. 2,419,713. Saw Blade Lubricant. E. L. Flood to Consolidated Vultee Aircraft Corporation.

This lubricant composition comprises 70-80 percent by weight of a wax with a melting point of at least 143° F., such as paraffin wax, carnauba wax, ceresin wax, or candelilla wax, 20-30 percent of a soda base grease, 4-5 percent of turpentine, rosin oil, or pine oil, and 0.5-0.7 percent of aluminum stearate. The soda base grease is preferably a mixture of sodium soap and a high viscosity lubricating oil, such as petrolatum. This lubricant composition maintains a lower temperature during the blade operation than other lubricants and thereby prolongs the life of the blade and increases its efficiency.

U.S.P. 2,420,068. Lubricant. G. W. Duncan and J. C. Zimmer to Standard Oil Development Company.

The lubricating oil composition consists of a mineral lubricating oil, 0.5-5 percent of an oil-soluble hydrophilic polyvalent metal-containing derivative of an organic compound with detergent properties, and 0.01-0.3 percent of an aliphatic primary amine containing 8-22 C atoms per molecule. The metal-containing compound can, for example, be an alkaline earth metal sulfonate, or alkylated phenol sulfide, and the amine can, for example, be octadecenyl amine, or hexadecyl amine.

U.S.P. 2,420,274. Heavy-Duty Motor Oil Composition. N. D. Williams and W. J. Backoff to The Pure Oil Company.

A lubricant additive is prepared from a saponified fatty semi-wax material containing in chemical combination therewith a small amount of a phosphorus sulfide. The product obtained is divided into two unequal portions. The major portion is heated for a short time to 300-350° F., sufficient to remove traces of moisture and objectionable odor but insufficient to decompose it. Thereafter this portion is reblended with the minor, unheated portion. A barium soap of wool-grease can, for example, be combined with P_2S_5 and then treated in the indicated manner. When added to mineral lubricating oil this additive imparts to the lubricant deteregent properties and lowers the pour point thereof.

U.S.P. 2,420,280. Lubricant and Method of Making Same. J. S. Yule and H. L. Moir to The Pure Oil Company.

A lubricant is prepared by cooking fatty oil, at temperatures not in excess of 340° F. until the product gives a good copper strip corrosion test. The sulfurized material is reacted with sufficient P_2S_5 to incorporate therein 0.2-0.6 percent P at a temperature of about 230° F., with 2-8 percent S at 270-300° F. for a period of time (2-6 hours) sufficient to cause the sulfur to become incorporated in the product in a loosely bound form. The material thus obtained can be mixed with mineral lubricating oil in a ratio of, for example, 82 percent of the latter to 18 percent of the additive.

Polish Output

Including imports from USSR and Hungary, refineries in Poland processed approximately 127,000 barrels crude oil during the month of February.

ABOUT OUR AUTHORS . . . . . and Other PERSONALITIES

Built a "Gearless" Back in Early Days

Albert E. Hickel, back in the days (1908) when he was with Galena Signal Oil Company at Parkersburg, West Va., assembled a "gearless" Metz automobile equipped with a two-cylinder, opposed-horizontal, air-cooled motor, friction drive (aluminum disc against a leather-faced disc) of which he was reminded when The Tucker Corporation announced forthcoming production of its "gearless," rear-engine drive car without conventional transmission, clutch, drive shaft and rear axle differential. "It looks like we are going back to more simplified cars," he commented in his letter submitting his article, *Forty Years of Automotive Gear Lubrication*, soon to appear in PETROLEUM REFINER.

Hickel

Hickel, a consulting lubricating engineer in Chicago since leaving Sinclair Refining Company, East Chicago, where he served 1925-45 as research lubricating engineer, is a native of Alsace, started with Galena Signal at Franklin, Pa., as chemist in 1902, went to Galena's plant at Parkersburg in 1907 and served as superintendent until 1919. Then he came to Texas for a three-year stint as refinery superintendent at Brownwood before joining The Texas Company at Port Arthur in 1922 as research lubricating engineer. He went with Sinclair in 1925.

Incidentally, Hickel says that K. E. Lyman, Tucker Development engineer, asserts the new Tucker can burn a low-octane or regular straight-run gasoline due to the special motor-head construction.

First Appearances Of Three Authors

Out of the program of the Division of Refining of the American Petroleum Institute in St. Louis June 2 and 3, three papers were selected for the July issue of PETROLEUM REFINER.

The authors, J. G. Housman of Standard Oil Company (Indiana) and E. W. Stothart, Grinnell Company, and Fred Van Covern are making their first appearances in the publication. In the first two instances that does not seem exceptional.

But how Fred Van Covern has kept his name out of PETROLEUM REFINER for all these years is difficult to comprehend. He has been dealing with statistics for so long that it seems incredible that so little of his calculations have dealt with the manufacturing division of the industry.

The three represent the scope of the program at St. Louis, the first meeting of the Division of Refining since the beginning of World War II.

Dr. Egloff Off To Europe Again

Beginning July 4 Gustav Egloff, director of research of Universal Oil Products Company, began a month of travel in Europe during which he is appearing before several technical societies in England, France, Belgium, Holland and Czechoslovakia.

His first paper was presented July 8 before the symposium sponsored by the Royal Institute of Chemistry at St. Andrews, Scotland, "Petroleum and Coal as Source of Materials for Chemical Derivatives."

July 17-24, Dr. Egloff will attend the Eleventh International Congress of Pure and Applied Chemistry in London, where he is scheduled to present the following paper: "Polymerization of Cracked Gases," "Catalytic and Thermal Cracking of South American Crudes," "Chemical Interdependence of Agriculture and Petroleum," "Alkylation of Paraffin Hydrocarbons," "Chemicals from Petroleum and Coal Tar as Source Materials." He will also participate in a meeting of the permanent council of the World Petroleum Congress to decide on a definite date for the next meeting of the congress.

Dr. Egloff expects to lecture before the Societe Belge pour l'Etude du Petrole in Brussels, and at the University of Delft, Holland. He plans to return to the United States by August 4.

DR. GUSTAV EGLOFF

Article Deals With His Pet Subject

William H. Reynolds, author of "Industrial Engineering in Refinery Maintenance," (page 123) admits in a letter to the editor that "it is certainly a satisfying feeling to be able to spread the word about one's own pet subject."

Reynolds

Reynolds, connected with Sinclair Refining Company's East Chicago refinery, is a 1938 graduate of Purdue University and has worked for Shell Oil Company, (Houston refinery), The Pure Oil Company, Chicago, Arthur G. McKee Construction Company, Cleveland, and Standard Oil Company (Ohio), where after the war (he was a lieutenant, j.g. in the United States Navy, assigned as junior officer aboard a submarine) he was head of Standard's newly-formed maintenance control division with duties of organizing the department for control of all plants maintenance. This included instigation of programs for improvement and cost reduction of maintenance through use of industrial engineering principles. His present Sinclair connection also is with the maintenance department.

Reynolds is a registered professional engineer in the states of Ohio and Indiana. He was one of those who instructed a group in job methods training during the war program of "Training in Industry." So that's his background.

Reynolds plans to follow up this general outline with additional articles covering specific applications of various phases of industrial engineering. It is not unlikely that these may appear in THE PETROLEUM REFINER.

Garner Contribution To Be His No. 2

Last month a welcome telegram arrived from James B. Garner, as follows:

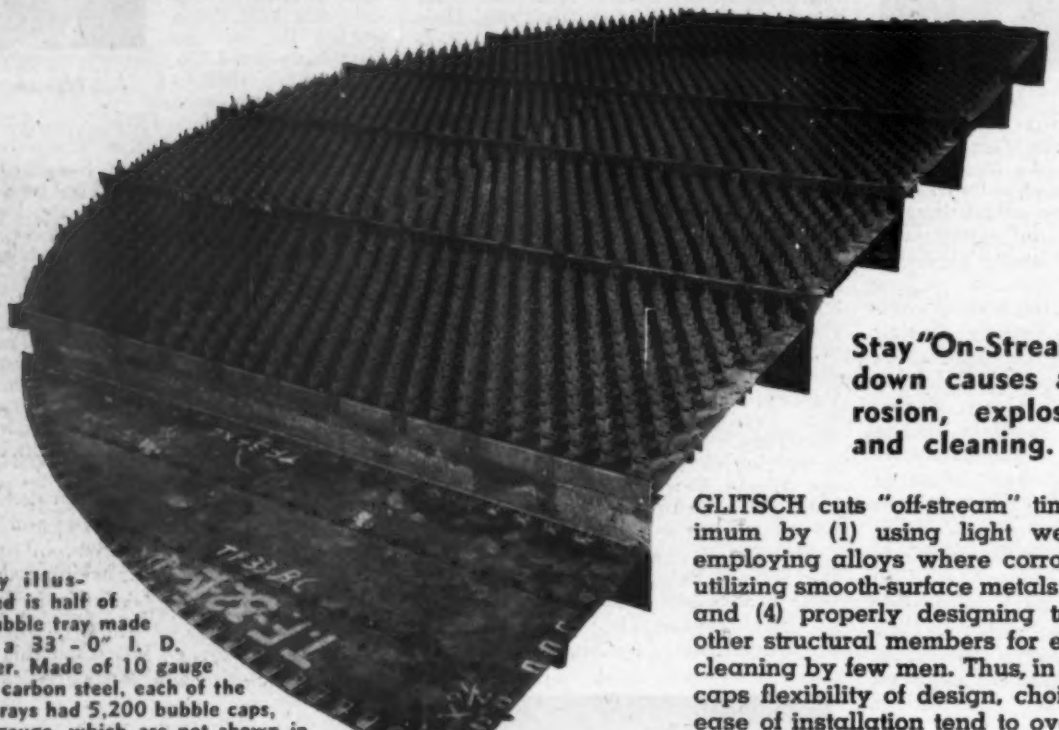
"HAVE CAREFULLY PREPARED ARTICLE ON "LIQUEFIED GAS INDUSTRY." WOULD YOU BE INTERESTED IN ITS PUBLICATION . . . "

There was a prompt response in the affirmative and the manuscript is now in process of preparation for early presentation.

This will be Garner's second appearance in PETROLEUM REFINER, as he prepared the manuscript on storage for the War Products number in October, 1942. Garner is holder of the chemical storage fellowship at Mellon Institute, Pittsburgh.

"ON-STREAM"

Glitsch LIGHT WEIGHT "TRUSS-TYPE" BUBBLE TRAYS AND CAPS ASSURE MAXIMUM "ON-STREAM" TIME



Tray illustrated is half of a bubble tray made for a 33'-0" I. D. tower. Made of 10 gauge low carbon steel, each of the 12 trays had 5,200 bubble caps, 12 gauge, which are not shown in the illustration.

Stay "On-Stream!" Major shutdown causes are coking, corrosion, explosion, inspection and cleaning.

GLITSCH cuts "off-stream" time to the very minimum by (1) using light weight materials, (2) employing alloys where corrosion is a factor, (3) utilizing smooth-surface metals to cut down coking, and (4) properly designing trusses, beams and other structural members for easy inspection and cleaning by few men. Thus, in GLITSCH trays and caps flexibility of design, choice of material and ease of installation tend to overcome present-day problems.

GLITSCH light weight trays and caps, because of the low heat capacity and the light weight construction, cool off and heat up faster than heavier trays. This means less "off-stream" time for inspection and cleaning out.

"Off-stream" time can mean anything from $1,000 to $10,000 a day. A few days saved can more than equal the cost of GLITSCH trays and caps. Many installations have actually paid for themselves before going "on stream".

MANUFACTURED UNDER U. S. PATENT NO. 2,210,808; NO. 2,309,309; NO. 2,338,925; NO. 2,341,091 AND OTHER PATENTS PENDING.

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"TRUSS-TYPE" BUBBLE TRAYS ● BUBBLE CAPS ● TOWER INTERNALS

NEW EQUIPMENT
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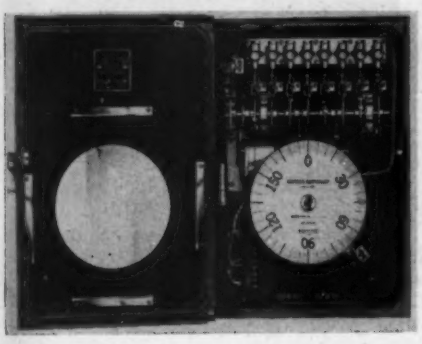
1—Cycle Controller

The Bristol Company, Waterbury, Connecticut, has introduced a new cycle control, model 6500, for timing mechanical and industrial operations.

In this controller, time measurement and pilot valve operation are handled by separate mechanisms. Separation of these two basic functions made possible a design that gives accurate timing of the factors under control, high speed and torque for pilot valve operation, and flexibility of application.

Timing is accomplished by a Telechron-driven aluminum disc on which



Bristol Cycle Controller

is printed a 25-inch time scale. The desired schedule of operations is incorporated into the controller by cutting notches with a notching punch on the time scale. The location of these notches determines the time of operation of the cam mechanism. Discs for new cycles or schedules of operation can be easily made. There are no air or mechanical connections between the timing disc and cam-operating mechanism. Time impulses are transmitted electrically.

The cams are individually adjustable and their setting does not require fine adjustment in order to get accurate results. Any sequence of operation can be obtained.

CHECK THE CARD AT PAGE 216

2—Dust Collector

Aget-Detroit Company, Ann Arbor, Michigan, is offering a bench-type dust collector, for laboratory and similar uses and especially designed for collecting dust from buffers, polishers and grinders. The model, No. 330, is self contained and requires no installation other than placing in position and plugging into a light outlet.

A quarter-horse motor drives a paddle wheel fan which is capable of clearing chips and dust from bringing lint and strings. The hood which is fastened on the Model 330, has a baffle, light fixture for illumination of the work and two removable trays for easy emptying of debris which drops from the work. Two trays also eliminate mixing accumulated dusts from wet or dry work. A flap on the leading edge of the hood reduces wheel carry-over. A toggle switch mounted on the front of the cabinet is convenient for starting and stopping the motor.

Removal of the collected dust and dirt is by means of a drawer from the left side of the unit. A hand crank on the side of the unit immediately above the dust drawer facilitates a quick and easy shake-down of the spun-glass filter material. This spun-glass filter material is cheaply and easily renewed after repeated shakings and following long intervals of service.

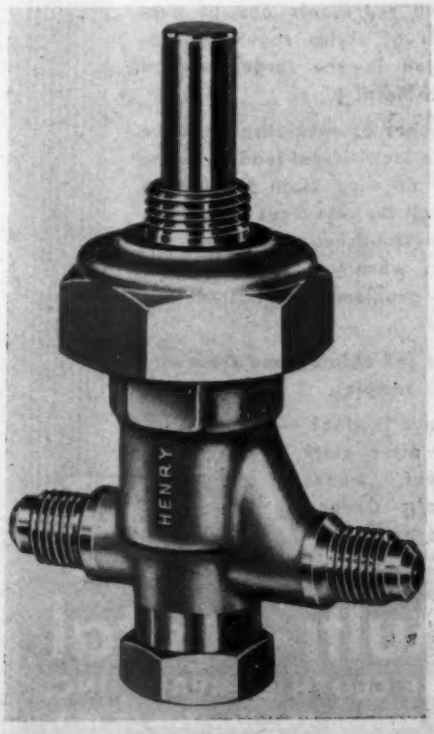
CHECK THE CARD AT PAGE 216

3—Packless Valve

The Henry Valve Company, 3260 West Grand Avenue, Chicago 51, Illinois, has introduced a new type of push-button packless valve. The valve has a forged brass body and is suitable for handling oil, air, water, or any substance not corrosive to brass. The valve is normally open and is designed for operations where either manual or automatic instantaneous valve operation is desired, and where leakage around conventional packing would be objectionable.

The Henry push-button packless valve has a renewable disc, renewable diaphragm, and a threaded collar around the push button, which permits it to be mounted through a flush panel opening. It is suitable for pressures up to 100 pounds. The valve can be furnished with male SAE, IPS, or female solder connections in sizes one-fourth inch through one-half inch.

CHECK THE CARD AT PAGE 216

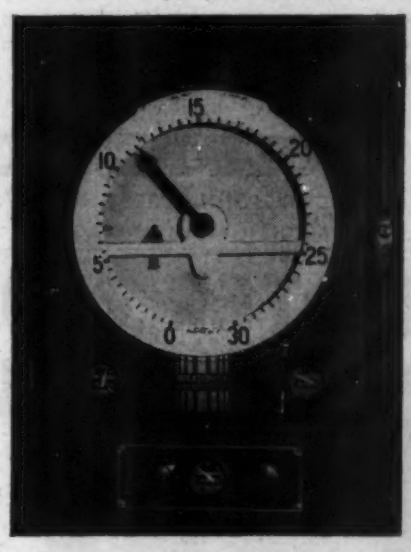


Push Button Valve

4—Pneumatic Control

A pneumatic control, just released by Leeds & Northrup, 4934 Stenton Avenue, Philadelphia 44, features rugged construction, faster action, more flexibility and compactness than previous L&N models. It can be applied to control temperature—using thermocouples, radiation-type detector tubes or resistance thermometers—pH, gas analysis (percent SO_2, etc.) and electrolytic conductivity. A wide selection of instruments is available for any type of control from simple proportioning to complete control with automatic droop-correction (reset) and rate action.

CHECK THE CARD AT PAGE 216



Pneumatic Control

5—Mitre Gear Box

Piezo Manufacturing Corporation, 110 East 42 Street, New York 17, has added a new line of mitre gear boxes to its line of products, the box being made with a mounting base for installation in any position. These precision mitre gears are designed for medium speed power drives or hand operation with 1:1 ratio, meet power and torque rating standards of the AGMA, and are furnished with either bronze or roller bearings. Hydraulic type grease fittings provide positive lubrication and oil seals prevent leakage.

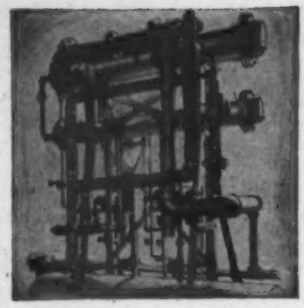
CHECK THE CARD AT PAGE 216

6—Electric Motor

Fairbanks, Morse & Company, Chicago, is now in production on its new type of electric motor, designated as an axial air-gap motor, "distinguished by the fact that the magnetic lines of force follow a path parallel to the shaft as compared to a radial path taken by the

VACUUM 99.99% PERFECT

This degree of vacuum referred to the average sea level barometer is maintained by the Croll-Reynolds five stage steam jet EVACTOR. If five stages sound complicated consider the fact that there are absolutely no moving parts. Each stage from a mechanical standpoint is as simple as the valve that turns it on. Numerous four stage units for maintaining industrial vacuum down to 0.2 mm. and less, and many thousands of one, two and three stage units are maintaining vacuum for intermediate industrial requirements on practically all types of processing equipment.



An engineering staff of many years experience has specialized on this type of equipment and has contributed toward the development of several vacuum processes which have revolutionized certain manufacturing operations, improved certain commercial products, and assisted in the development of new products.

Water jet Ejectors marketed under our trade name HYDRO-VACTORS and vacuum cooling units well known to industry as Croll-Reynolds CHILL-VACTORS round out this line of specialized equipment.

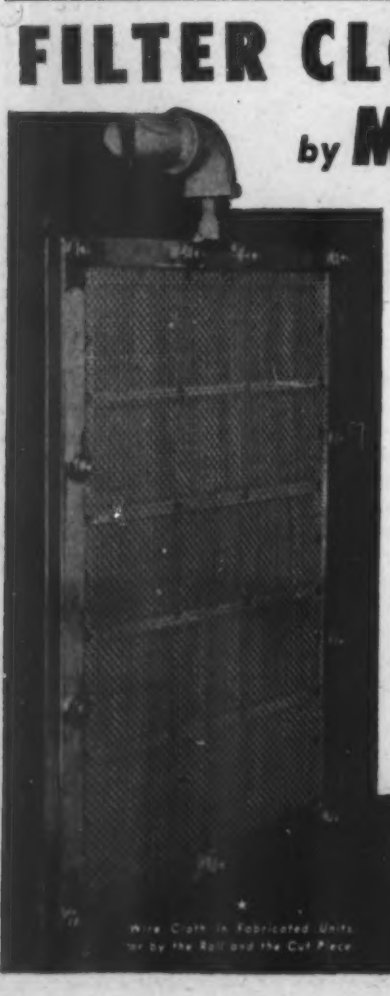
CROLL-REYNOLDS CO.

17 JOHN STREET, NEW YORK 7, N. Y.

CHILL VACTORS STEAM JET EVACTORS CONDENSING EQUIPMENT

CROLL-REYNOLDS

FILTER CLOTH UNITS by MULTI-METAL



Wire Cloth in Fabricated Units or by the Roll and the Cut Piece

The all-stainless steel filter leaf shown represents one of hundreds of styles regularly fabricated in the large, modern Multi-Metal plant.

34 years of specialization have made Multi-Metal leaders in the field of wire cloth fabrication and all the resources of a large, well-established concern are yours when you put your filter leaf problems in Multi-Metal's hands.

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Fairbanks Morse Motor

magnetic flux in the conventional motor."

The new motors, available in sizes from one-third h.p. to 10 h.p., are suitable for horizontal or vertical flange mounting or on an angle base for belt drive. Other features of the motor have been further described in literature from the manufacturer as follows:

The outstanding features are space and weight reduction, the new motor being less than half the size of the conventional type motor and weighing less by approximately 30 percent, yet retaining all the necessary characteristics of sturdines and power requirements.

Other unique features, in addition to its improved appearance, are the simplicity and speed with which this motor can be inspected, cleaned and lubricated; a cooler rotor; much greater acceptability as flange-mounted motor with less overhang for unlimited machine application.

CHECK THE CARD AT PAGE 216

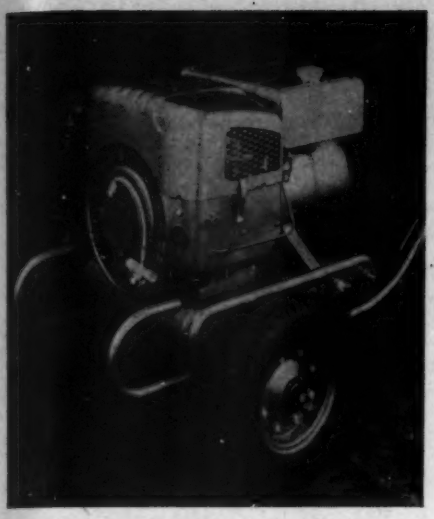
7—Portable Welder

Hollup Corporation, 205 West Wacker Drive, Chicago, is offering a portable gasoline engine driven welder. The manufacturer is a subsidiary of National Cylinder Gas Company.

Because of light weight—315 pounds—and compact construction, the unit is portable on the job as well as to the job. It fits easily into the back of a station wagon, or even the trunk compartment of some cars, and can be lifted by two men. Light weight is achieved through use of aluminum wherever practical. The generator and engine are directly connected, forming a single compact unit.

The welder is rated at 150 amperes at 30 volts on 50 percent duty cycle. It has a four-cycle, two cylinder, opposed design engine.

The manufacturers point out a minimum loss of amperage since the welder can be brought so close to the job that



Portable Welding Unit

usually only 20 feet of cable is necessary, with consequent reduction in cable investment.

Electrodes up to and including 5/32-inch and certain types of 3/16-inch may be used with the welder. Exceptional arc stability and economical operation are claimed. Receptacles for extension cords on the machine provide for emergency lighting. Two models are available. One is mounted on a two-wheel dolly with pneumatic tires; the other is a stationary type with a guard frame.

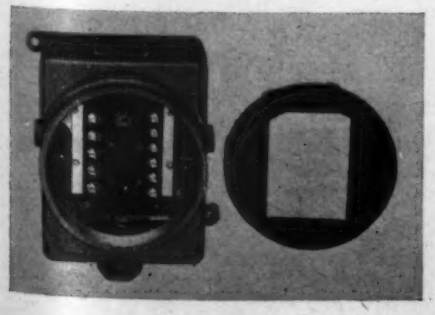
CHECK THE CARD AT PAGE 216

8—Level Control Unit

Photoswitch, Incorporated, 77 Broadway, Cambridge, Massachusetts, has a new design of a level control instrument, especially for applications in chemical processing.

Level Control Type 10CB1X is an alternating current control that combines a probe circuit and transformer in a unique manner to operate a direct current relay, insuring heavy contact pressures and long relay life. Two probe rods wired to the control project into the tank to the levels corresponding to the low point where pumping is to start, and the high point at which pumping stops. When the level of liquid falls below the lower probe, the level control closes the electrical circuit controlling the pump or valve. When the liquid rises to the level of the upper probe, the fluid acts as conductor of the minute current at low voltage required for the operation of the relay. Opening of the electrical circuit results, and pumping operations stop.

Level Control Type 10CB1X is designed for installation not only under



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Fluorescent Green: H.W. 185%

Solubility ---------- readily and complete
Color ---------- unchanged by transmitted light

STABILITY:

light ---------- fast
heat ---------- stable
storage ---------- stable

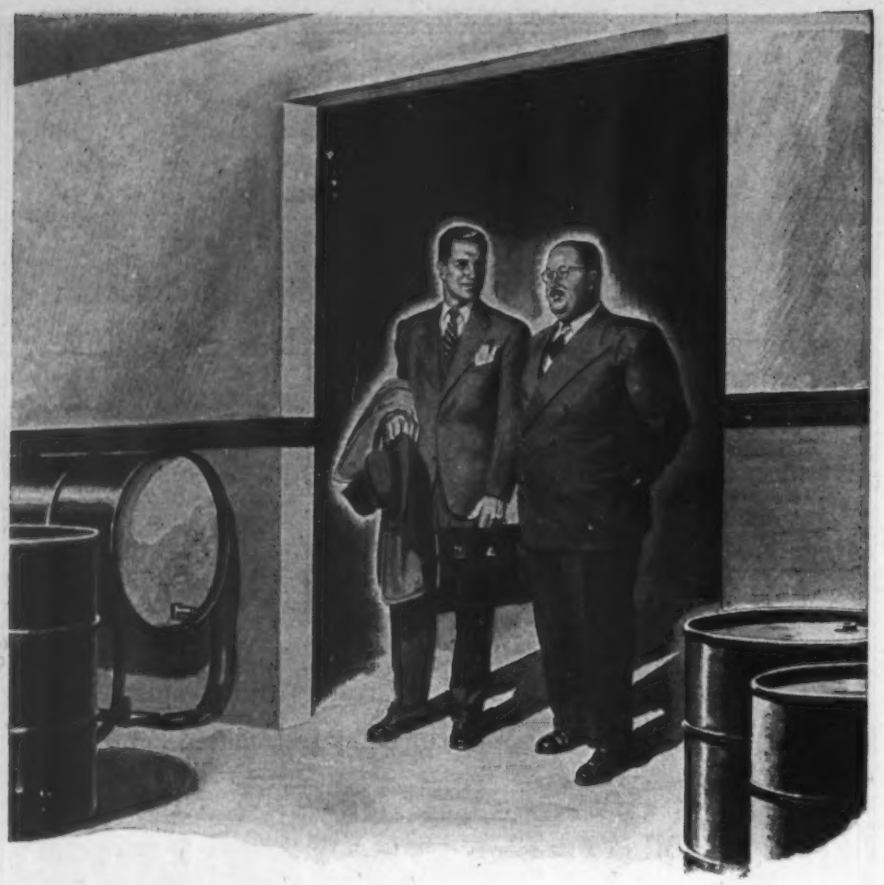
TESTS:

carbon residue ---------- unchanged
fire ---------- unchanged
flash ---------- unchanged

Leading lube refiners in the United States and abroad have used Wilmot & Cassidy products for fifteen years. *For samples, prices, and information please write to:*

Wilmot & Cassidy, Inc.

108 Provost St. Brooklyn 22, New York



"If a fire starts here, a built-in extinguishing system is your best bet"

Wherever you have a fire hazard involving storage of flammable liquids—paints, solvents, oils . . .

You'll find it worthwhile to talk it over with a Kidde representative!

He's an old hand at fire protection problems. He can study your specific hazard, and suggest the type of extinguishing equipment best suited to your needs—built-in systems, wheeled units, portables.

All types of *Kidde* carbon dioxide extinguishing equipment, of course, offer the same basic advantages. Fast, sure action against fires in flammable liquids and electrical apparatus. No corrosion of metals, no contamination or dilution of liquids. No after-fire mess. Carbon dioxide is deadly to fire—harmless to everything else!

Walter Kidde & Company, Inc., 748 Main Street, Belleville 9, N. J.

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Kidde

FIRE PROTECTION HEADQUARTERS

normal industrial conditions but also under some of the most exacting conditions encountered in the chemical processing field.

It is supplied in an explosion-proof housing, or more generally in a pressed steel, dust-tight enclosure. The explosion-proof housing is used on installations where it is desirable that the level control which carries the current required to operate the pump be explosion-proof, even though it is permissible to pass a minute electrical current at low voltage through the liquid itself.

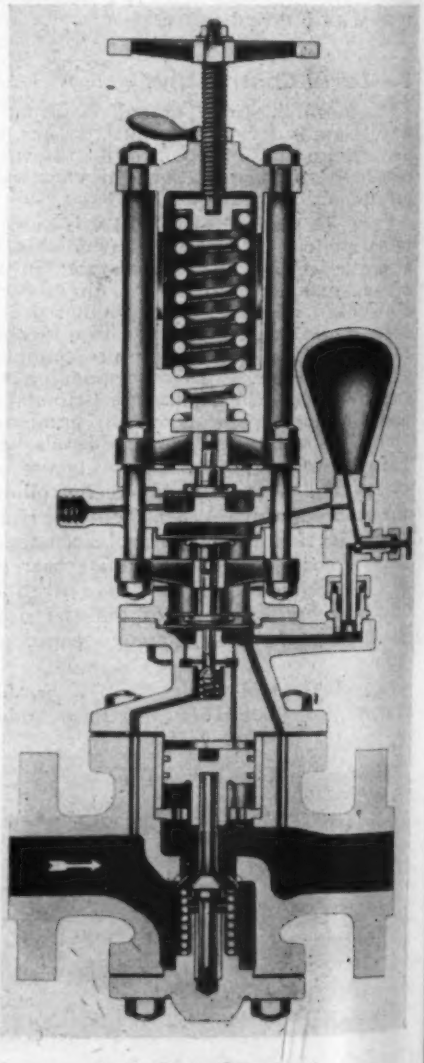
CHECK THE CARD AT PAGE 216

9—Pump Governor

Leslie Company, 169 Delafield Avenue, Lyndhurst, New Jersey, has designed a line of pump governors, especially for high accuracy of control and high resistance to wear and erosion.

Hard surfaced seat rings, 800 Brinell hardened stainless steel main valve and 500 Brinell cylinder liner reduce wear where it is usually felt the most. The hard seating surface is applied as a welded section to seat rings of bronze governors and to the main body of steel governors. Combined with the 800 Brinell main valve it provides a long life combination that has never before been offered as standard equipment.

Other design features include instrument accuracy of regulation, wide spring range which permits settings without



Leslie Pump Governor

change of spring or diaphragm, single seated valve, no packing or stuffing boxes, complete interchangeability of replacement parts without removal of the body from the line.

Available in sizes from ½ inch to 4 inches for inlet pressures from 40 to 600 psi at 750° F.

CHECK THE CARD AT PAGE 216

10—Steam Cleaning Plant

Clayton Manufacturing Company, El Monte, California, has designed a new type of steam cleaning machine, based on experience gained from its production of cleaning units for military service during the war.

This new unit, model C, includes such features as automatic soap injection, pressure atomizing burner, fully insulated fire box, electric ignition, protective fuel cutoff in case of water failure and a positive displacement pump. All working parts are easily accessible by lifting a hinged hood.

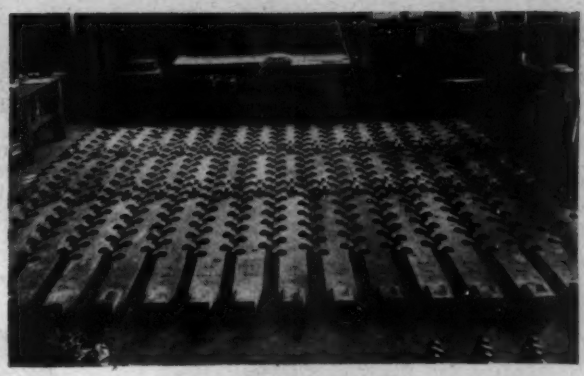
CHECK THE CARD AT PAGE 216

Steam Cleaning Unit

11—Lubricated Pump Seal

Durametallic Corporation, 2104 Factory Street, Kalamazoo, 24F, Michigan, has adapted force-feed lubrication to its mechanical seal for uses where hydrocarbons, boiler feed water and other refining products are being pumped. The principal of the combination is that lubricating oil serves to partially balance off the pump or vessel pressure and positive lubrication is supplied automatically to wearing parts of the seal at the point of contact. It is automatic and the amount of lubricating oil can be set as required and no return circulating

DURALOY
TUBE SUPPORTS



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Because of this, we can fairly claim to be "specialists" in the high alloy casting field . . . and as such, believe we can serve refineries, not only with tube supports such as illustrated, but with pump liners, centrifugally cast tubes and pipes, fan blades and other high alloy castings needed in refineries.

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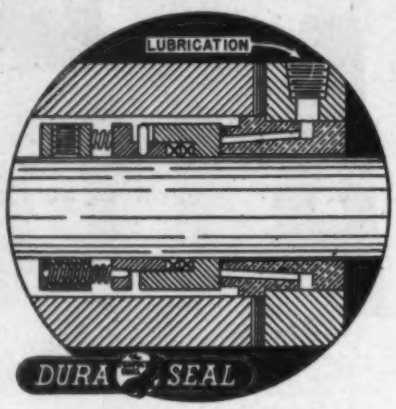
pipes are necessary as excess lubricating oil will drain to atmosphere and not contaminate the process fluid.

It is designed for pressures up to 500 pounds. The combination can be installed on existing equipment and is readily adaptable to standard stuffing boxes of equipment having rotary shafts without end play. It will serve also on outside stuffing boxes for corrosive or gritty fluids at low pressures, also under vacuum.

CHECK THE CARD AT PAGE 216



Lubricated Pump Seal

12—Static Detector

Davis Emergency Equipment Company, Inc., 164 Halleck Street, Newark 4, New Jersey, has designed a portable electric instrument for use in detecting electrostatic conditions. The meter is calibrated in terms of static volts and is sensitive enough to detect static charges of fractional volts, either negative or positive.

There are two sockets on the top of the instrument in which an air terminal is inserted, one for detecting negative charge, the other for positive. If the air terminal in the socket for detecting negative charge and the meter needle turns downward instead of upward, the static charge is positive and a change of the air terminal to the opposite socket is indicated.

Operation of the instrument is simple. With the operating switch turned on, the range switch is then turned to the low range position and balanced to zero. As the operator comes in the vicinity of a body charged with static electricity, the needle of the meter will begin to fluctuate, indicating that the area has within it a charged body. The range switch is then turned to the high range position and as the detector comes closer to the charged body, the meter needle will move higher on the scale.

Static Detector

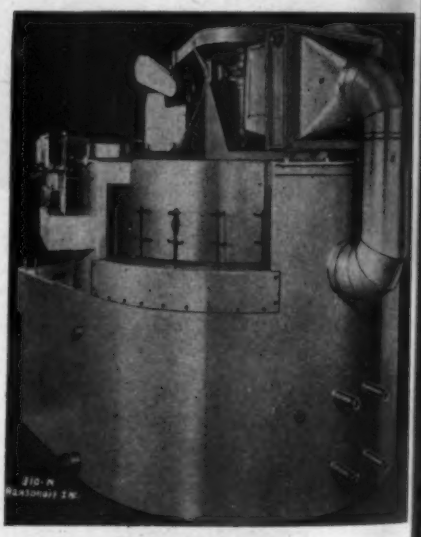
The instrument is designed to measure both above and below the sparking voltage. The low input capacity and high input resistance contribute to accuracy of readings.

CHECK THE CARD AT PAGE 216

13—Bottle Washer

The Industrial Systems Company of 341 South Central Avenue, Los Angeles 13, California, announces the manufacture of a special washing machine for use in the cleaning of oil sampling bottles and cans up to one gallon capacity. The machine is designed to handle approximately 3000 various sized bottles and cans per each 8 hours.

It is divided into five sectors. The outer sector is used for loading and unloading, and the other four sectors are used for washing and rinsing. Machine is equipped with a rotating table in the form of a wheel. The work is placed on top of the cone fixtures and held in place by means of sliding weights. The table is supported by a central shaft with a flanged bearing taking the thrust.



Laboratory Bottle Washer

Table is hand rotated and equipped with a spring loaded stop. The outer edge of the table is supported by means of rollers equipped with pillow blocks.

The work is loaded onto cone fixtures and held in place by means of sliding weights. After all the work is loaded onto the table, the table is rotated by hand through to the next station where it receives a live steam rinse, and then receives a solvent wash, alkali wash, and finally a hot water rinse.

All solutions are handled by vertical centrifugal pumps designed without stuffing boxes or packing glands and with all bearings above the solution level.

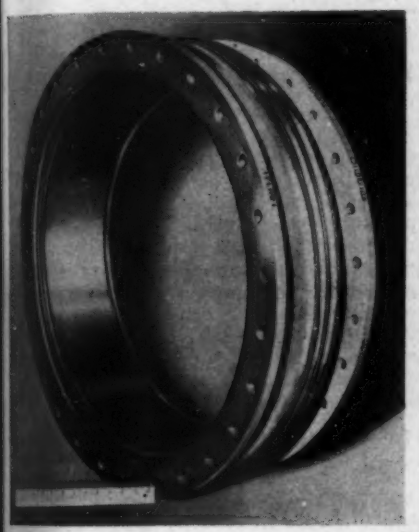
Tanks extend from the side of the machine for ease in cleaning, and the extending portions are equipped with substantial steel covers. Tanks are complete with chip pens, chip baskets and overflow skimming dams so that all cleaning compound and rinse water must pass through these baskets before

returning to the pumps to separate out all chips or refuse. Chip baskets consist of tubular wire mesh sections, and each section may be easily removed for cleaning and dumping the accumulated refuse.

CHECK THE CARD AT PAGE 216

14—Expansion Joint

MagniLastic Division, Cook Electric Company, Chicago 14, has announced quantity production of a standard line of new low-pressure large-diameter packless expansion joints, ranging in sizes from 14 inches to 6 feet in diameter. Normally supplied in Type 347 stainless steel to accommodate pressures up to 30 psi, other metals may be specified when required.



MagniLastic Expansion Joint

The photograph shows a 36-inch unit with 3 bellows flanges for a 3-inch total movement. For greater travel requirements, additional flanges may be added. Complete information, including specifications and operating conditions for these low-pressure large-diameter expansion joints and other standard and special joints are included in a revised Catalog M-620, available upon request.

CHECK THE CARD AT PAGE 216

15—Volatile Liquid Pumps

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has issued a new folder, W-411-B10, which gives engineering details, with drawings, of its horizontal duplex power pumps specially designed for volatile liquids.

CHECK THE CARD AT PAGE 216

16—Mixed Flow Type Pump

Peerless Pump Division of Food Machinery Corporation, 301 West Avenue, Los Angeles 31, has prepared information on its mixed flow type pump as Bulletin B-148, of 24 pages with illustrations. Described characteristics of the pump, embodying essential characteristics of both centrifugal and axial flow pumps, include ability to move liquids against maximum heads and with minimum submergences, adaptation of shal-

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lower sumps, utilization of higher speed motors against medium heads and installation in minimum space.

The bulletin gives full description, typical and unusual installations, applications, and engineering advantages, being completely illustrated with cross sectional drawings, descriptive engineering data and diagrammatic sketches of pump station arrangements.

CHECK THE CARD AT PAGE 216

17—Protective Coatings

Prufcoat Laboratories, Incorporated, 63 Main Street, Cambridge 42, Massachusetts, has issued a new folder describing its line of protective coatings. It lists chemical agents the coatings resist, a variety of case histories, and application information.

CHECK THE CARD AT PAGE 216

18—Process Pumps

Bulletin 6000 issued by National Transit Pump and Machine Company, Oil City, Penn., describes Type ES, a new single stage centrifugal pump designed for use where temperature or pressure is very high, liquids are handled near boiling point, continuity of operation is essential, suction pressure is extremely high, etc. Twelve sizes of 22 impeller designs are offered with capacities from 40 to 1500 PM.

CHECK THE CARD AT PAGE 216

19—Bulk Station Pump

Bulletin No. 46-7000 on its line of bulk station pumps has been issued by the Pump Division of Byron Jackson Company, Box 2017, Terminal Annex, Los Angeles 54, and will be sent on request. Covered are the "TLB" pump, a centrifugal type pump, which is designed to handle gasoline, butane, diesel fuels, lubricating oils and other hydrocarbons. A standard unit has a capacity range of 600 gpm, discharge pressure to 150 psi, temperature to 150° F.

CHECK THE CARD AT PAGE 216

20—Mass Spectrometer

Consolidated Engineering Corporation, Pasadena, Calif., has issued a brochure for presentation of its new mass spectrometer, Model 21-102. It gives a complete description of the mechanism as well as details for using the instrument in the analysis of petroleum fractions. This model is adaptable to microchemical examinations and in the petroleum field it furnishes complete breakdowns of stream samples. It may be used in the analysis of naphtha streams as well as the lighter hydrocarbons.

CHECK THE CARD AT PAGE 216

21—Safety Valve Disc

Manning, Maxwell & Moore, Inc., Bridgeport, Conn., has for sale a new safety valve for air compressors, utilizing a nylon disc. The use of nylon as a material for safety valve seats is new. So far, nylon is the only material found which possesses all the essential characteristics of wear resistance, hardness and flexibility. This new valve utilizes a ny-

lon disc working against a bronze seat. Nylon, unlike other seating materials which have been tried, will not flow or creep under spring compression nor stick or weld itself to the seat. It is just flexible enough to conform exactly to the seat and has a recovery characteristic which quickly seals off the slightest air leakage after the valve pops.

This new valve meets all ASME requirements for air compressor service. It has been flow-tested and discharge capacities are guaranteed.

CHECK THE CARD AT PAGE 216

22—Nickel Steel Tubing

New 9-percent nickel steel tubing is described in a bulletin, TR-508, by The Babcock & Wilcox Company, 85 Liberty Street, New York 6. Mechanical and working characteristics, heat treating behavior and weldability of the tubing are set forth together with suggested fields of application (handling of alkaline solutions, liquefied gases, mildly acidic conditions, etc.).

CHECK THE CARD AT PAGE 216

23—Butterfly Valves

Fisher Governor Company, Marshalltown, Iowa, has compiled data on its heavy duty steel body butterfly valves in bulletin No. 77. These valves are designed especially for motor valve operation with cable drive mechanism from pneumatic motor to rotary shaft of the butterfly valve.

CHECK THE CARD AT PAGE 216

24—Strainers

Bulletin No. 224 describes the new type SY strainer and the old type S strainer manufactured by A. W. Cash Valve Manufacturing Corporation, Wabash and Morgan, Decatur 60, Ill. The type SY strainer is built to conform with standard cast iron screwed fitting specifications for pressures up to 250 psi, furnished standard with a convenient blowdown for easy cleaning and with a wide selection of screens. A list of all Cash-Acme bulletins also is shown.

CHECK THE CARD AT PAGE 216

25—Air-Line Respirators

Mine Safety Appliances Company, Braddock, Thomas and Meade Streets, Pittsburgh 8, has available a new Bulletin CS-23, descriptive of its air-line respirators, auxiliary parts and equipment.

CHECK THE CARD AT PAGE 216

26—Hortonspheres

The Chicago Bridge and Iron Company, 332 South Michigan Avenue, Chicago 4, Illinois, announces the publication of a new 8-page booklet, "The Hortonsphere." It describes the reduction of evaporation losses from highly volatile liquid by storing them under pressure in Hortonspheres. The correct storage pressure required to prevent standing losses from volatile liquids can be read directly from the chart included in this booklet. There is also a chart for determining the vapor pressure of the product to be stored at a given temperature. Gauging methods are described and photographs of three typical gauging units are shown. A copy of the booklet will be sent on request.

CHECK THE CARD AT PAGE 216

27—Nickel and Alloys Handbook

A compressed handbook and guide "Nickel and High Nickel Alloys" is being distributed by The International Nickel Company, 67 Wall Street, New York 5. Written by Dr. Norman E. Woldman, consulting metallurgical engineer and former chief metallurgist for Bendix Aviation Corporation, it originally appeared in the technical press. In addition to information on nickel, monel, inconel, and associated alloys it also includes material on such other alloys as the Hastelloys and illium. Reports on properties, heat and corrosion resistance, as well as modern fabrication and finishing practices are included.

CHECK THE CARD AT PAGE 216

28—Refinery Burners

Peabody Engineering Corporation, 580 5th Avenue, New York, has issued Bulletin 703, covering its type MU oil refinery burners. Diagrams show operation both of the Peabody Type M steam atomizing burner with removable gas ring and the Type T steam atomizing burner with removable gas ring.

CHECK THE CARD AT PAGE 216

29—Industrial Control Devices

Brown Instrument Company, Philadelphia 44, has published its Catalog 8302 as "Industrial Control Devices." Industrial control devices and safeguards are described along with schematic diagrams, dimensional drawings as well as photographs of installations.

CHECK THE CARD AT PAGE 216

30—Flowrator Instruments

Fischer & Porter Company, Hatboro, Pennsylvania, has a new bulletin describing its Flowrator instruments for measuring flow rate of liquids and gases. It includes descriptions and illustrations of instruments both assembled and disassembled. Numerous new accessories are shown, including a horizontal line adapter which makes it possible to insert these members as easily in horizontal runs as in vertical pipes. Details of front and rear panel mountings, rear lighting arrangements, steam heating coils and alarm devices are among the items included.

CHECK THE CARD AT PAGE 216

31—Masks

Mine Safety Appliances Company, Braddock, Thomas and Meade Streets, Pittsburgh 8, Pennsylvania, has Bulletin B-16, which describes its new M. S. A. Front-Type demand mask. The bulletin is available by writing the company.

CHECK THE CARD AT PAGE 216

32—Forged Nuts

Jos. Dyson and Sons, Inc., 5125 St. Clair Street, Cleveland 14, Ohio, has prepared a folder for users of large forged nuts. It is illustrated to give engineers technical knowledge of the products.

CHECK THE CARD AT PAGE 216

Tank Car Cleaning Costs Less The Oakite Way!

YOU can put a big dent in tank car cleaning costs by using the Oakite Interior Tank Car Cleaning Unit Model 324 in combination with recommended Oakite materials.

Clean More Cars per Day

This built-for-the-job Oakite Unit cleans by discharging a fire-safe, hot Oakite solution under pressure against your tank car interiors. Two opposing nozzles, revolving on both horizontal and vertical axes give off knife-like sprays of fast-acting Oakite solution that reach every inch of fouled surfaces. Important rinsing operation can be completed with same equipment. Steaming out time is eliminated. Thus you clean more cars per day . . . save valuable time . . . speed up turnaround of vital rolling stock.

Free Service & Data

Your local Oakite Technical Service Representative will gladly give you all the details of this time-saving tank car cleaning method. Ask him to bring along a copy of the Oakite Petroleum Digest which describes this and 87 other cleaning jobs. No obligation either way.

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It fights fire with the water available—maintains its fog pattern under low pressures in emergency.

Fine but forceful fog gives maximum cooling and quenching effect and drives to the base of the fire in spite of drafts and turbulence.

Also—

Blaw-Knox offers Standard Wet and Dry Pipe Systems, as well as Thermostatically Controlled Pre-Action and Deluge Systems.

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About EQUIPMENT—SERVICE Suppliers

Mason-Neilan Names Brown Manager at San Francisco

John W. Brown, sales engineer, has been appointed manager of Mason-Neilan Regulator Company's San Francisco office located at 198 Second Street.

John W. Brown

Brown is a mechanical engineer and formerly was connected with the instrument department of Standard Oil Company of Ohio. He came to Mason-Neilan in 1945, spent more than a year in the engineering department, then became sales engineer in Mason-Neilan's Pittsburgh office.

He assumed his new duties May 1.

Vollmer Is Elected Director Of A. O. Smith Corporation

M. J. Vollmer, assistant secretary and assistant treasurer of A. O. Smith Corporation, has been elected a director to replace John Leekley, resigned.

M. J. Vollmer

Vollmer joined the A. O. Smith Corporation in 1929 after graduating from the Wharton School of Finance, University of Pennsylvania. Starting in the automotive sales division, he spent some time in budgeting and time study work, and then became special assistant to W. C. Heath, then vice president. He worked in factory management as assistant to J. M. Floyd, vice president in charge of manufacturing, and later helped to establish the function of a controller's office. In 1939 he resumed his post as assistant to Mr. Heath, who had become president of the company and in 1945 he was appointed assistant secretary and assistant treasurer.

Allis-Chalmers New Unit For Turbo Power Development

A new turbo-power development department in the engineering development division of Allis-Chalmers Manufacturing Company will be headed by R. C. Allen who has been named manager and chief engineer. W. A. Yost, formerly assistant manager, succeeds Allen as manager of the steam turbine department.

The new department will particularly pursue turbo-power developments for ships, locomotives and stationary plants, based on extensive past experience with Houdry gas turbine-compressors, the gas turbine-drive aircraft superchargers and jet propulsion units, and an experimental 1500-degree F. marine gas turbine unit built for the Navy. One project currently under way is a 3750-horsepower coal burning locomotive gas turbine.

Allen, who holds more than 60 patents and is the author of numerous papers on steam and gas power machinery, joined Allis-Chalmers in 1936. Yost came to Allis-Chalmers from the Elliott Company in 1943.

Air Reduction Names Wallace District Manager

H. C. Wallace has been promoted to the management of the Louisville District of Air Reduction Sales Company to succeed R. S. Moore, who died recently. Wallace has been assistant manager of the district since 1944 and has spent 18 years in various activities in this district, where he began as an order clerk.

H. C. Wallace

He went to work with the firm in 1929 and after duties in the office became a salesman and finally assistant manager.

In his new duties he will be responsible for operation of all plants and offices in the Louisville district, which covers Kentucky and Tennessee and part of Indiana. The company has three plants in Louisville and one in Nashville. His headquarters will be in the Louisville district office.

Mixing Equipment Names Eastern Sales Representative

The Maleson Company, Philadelphia, has taken over the territory formerly handled by J. E. Snyder for Mixing Equipment Company. Its representatives will cover the southern section of New Jersey, all of Delaware, a major portion of Maryland and the east central portion of Pennsylvania, formerly contacted through the New York offices of Mixing equipment through Glenn J. Moorhead, eastern divisional manager.

Customer contact engineers of the Maleson Company are M. S. Maleson, Leonard Maleson, E. Brosius, J. C. Reynolds and S. R. Gerhart.

Weston Makes Changes In List of Officials

With the promotion of Earl R. Mellen to president, Weston Electrical Instrument Company, began following out the policy of transferring executive duties to younger officials through a transition period. In the change Caxton Brown, former president, became chairman of the executive committee, a post recently created. Edward F. Weston, son of the founder of the firm, was reelected chairman of the board, a post he had held since 1944.

Other officials are: H. Leigh Gerstenberger, vice president in charge of sales; Reginald R. Lambe, vice president in

charge of manufacturing; John H. Miller, vice president and chief engineer; Ross Nichols, secretary and treasurer; F. G. Hawthorne, comptroller.

Mellen has been executive vice president and treasurer of the firm since 1944. He has been with the corporation since 1917.

Automatic Sprinkler Forms South American Subsidiary

Automatic Sprinkler Company of America has formed an affiliate, Automatic Sprinklers de Beasil S. A., with headquarters at Sao Paulo, where plans for a factory are nearing completion. President of the affiliate is Clyde M. Wood, who has been in Brazil since November, 1945.

C. M. Wood

He has been with the company for more than 30 years and will now devote his time to the introduction of equipment and methods for fire protection.

Associated with him is Almeida Riberio, vice president, who has been engaged in the import and cotton business in Brazil for many years. Other officials include John M. Coleman and Floyd F. Thornton, together with a staff of local personnel.

Offices are at Praca da Se 371, Salas 709-12, Sao Paulo, Brazil.

Courouleau With Blaw-Knox In Chemicals Plant Division

The Chemicals Plant Division of Blaw-Knox Construction Company announces the affiliation of Pierre H. Courouleau as consulting engineer specializing in activated carbon installations for the recovery of volatile solvent vapors. Prior to joining Blaw-Knox, Courouleau was director of engineering for Carbonisations et Charbons Actifs, of Paris, France, and supervised the design and erection of solvent recovery plants in England, France, Spain, Italy, and North Africa.

This new division of Blaw-Knox will be directed by Dr. R. E. Benson.

American Car and Foundry Names Hardy as President

Charles J. Hardy, Jr., who heretofore had served American Car & Foundry Company as its executive vice president, has been elected to the presidency, succeeding F. A. Stevenson, resigned.

Hardy served as an officer in the United States Naval Reserve in World Wars I and II. He is a graduate of Williams College, holding the degree of Bachelor of Arts, and is a member of the bar of the state of New York.

Stevenson had been associated with ACF for more than 40 years in various capacities.

Rudolph Furrer

Charles J. Hardy, Jr.

Another ACF change is the election of Rudolph Furrer as vice president in charge of engineering, succeeding Edmund Dana Campbell, recently retired because of health reasons.

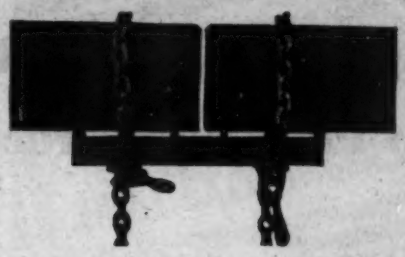
Furrer served on the War and Metallurgy Committee and as a special consultant in Ordnance Research and Development during World War II. Prior to his ACF connection he was with Allis-Chalmers Manufacturing, A. O. Smith Corporation and United States Steel Corporation.

E. D. Bullard Company Names Texas Distributor

Engineering Supply Company, 2656 Main Street, Dallas, has been named Texas distributor for E. D. Bullard Company, manufacturer of industrial safety equipment. Henry C. Coit is president of Engineering Supply Company and M. E. Wink is vice president.

Kimble Glass Names Division Sales Heads

Kimble Glass Division of Owens-Illinois Glass Company has appointed Edwin J. Rhein sales manager of the scientific division, E. B. Dennis, Jr., sales manager of the container and accessories



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division and Edward Charlesworth sales manager of the tube and rod division.

These changes are a part of the integration of the former Kimble Glass Company into the new status as a division of Owens-Illinois. Both Rhein and Dennis will transfer their departments from Vineland, N. J., to Toledo.

Foster Wheeler Places Bell In Charge of Dallas Office

J. H. Bell, assistant vice president of Foster Wheeler Corporation and for two years head of its public relations and advertising department, has been appointed sales manager of the company's newly-created Dallas district, which embraces parts of Texas, Oklahoma, Mississippi and all of Arkansas. Dallas will be headquarters.

J. H. Bell

Bell has been with the organization since 1923. He worked in various departments until 1926 when he became associated with sales in New York where he was made sales manager in 1935.

In 1936 Bell was appointed assistant vice president and given the duty of coordinating purchasing, expediting and production. In 1942 he became the company's liaison with the WPB and other agencies on all Foster Wheeler petroleum refinery division contracts. After V-J day Bell was assigned to the public relations division and later was placed in charge of the division in addition to his regular sales work.

Bell is a native of San Antonio, Texas. He attended the West Texas Military Academy, the Culver Military Academy, and Virginia Polytechnical Instiitute.

Bevarly Promoted in Girdler's Votator Division

The Girdler Corporation, Louisville, Kentucky, has announced the appointment of H. W. Bevarly to the post of assistant chief engineer of its Votator Division.

H. W. Bevarly

His experience with division dates back to 1929. Previously he had been engaged in extensive activities including that of machinist, mechanical draftsman and a specialist in refrigeration work. In the Votator division he has had charge of installing processing plants in England, Australia and South America.

The Votator Division of the Girdler Corporation is devoted to the design and installation of continuous heat transfer equipment in the processing industries.

Named Steel Sales Assistant

John R. Johnston has been named assistant general manager of sales, Carnegie-Illinois Steel Corporation, Pittsburgh, a United States Steel subsidiary. He has been with the company for 22 years.

Mullestein Heads Field Sales for Lukens Steel

W. E. Mullestein has been named manager of field sales for Lukens Steel Company and subsidiaries. He succeeds Arthur J. O'Leary, who died recently. He has been with the company since 1945 as manager of the Coatesville district sales office.

W. E. Mullestein

Mullestein is a graduate of Cornell University in civil engineering. Later he studied law at New York University and for three years was with a firm of patent lawyers. Then he joned the Austin Company as field engineer and construction superintendent. In 1939 he was associated with the American Iron and Steel Institute, as engineer and secretary of the committee on building codes.

Early in 1942 he went to Washington as a member of the staff of the War Production Board, where he served in its facilities bureau and held successively positions as head industrial and construction specialist, chief of the material and equipment requirements branch and director of the progress and scheduling division.

Carr Brothers Company To Represent Hammel-Dahl

Carr Brothers Company, Houston, has been named New England Sales representative for Hammel-Dahl Company, Providence, Rhode Island.

Frank J. and Arthur T. Carr

The firm is composed of Frank J. Carr and Arthur T. Carr, brothers, who have set up a sales organization to represent manufacturers of industrial equipment in a territory they have previously serviced as representatives and sales engineers.

Edward S. Budd Promoted By Cooper-Bessemer

Edward S. Budd has been named manager of the engine and compressor parts department, as reorganized by the Cooper-Bessemer Corporation, Mt. Vernon, Ohio. He has been with the company for 22 years and is assistant secretary of the company.

In the position of head of the parts department he will be responsible for the establishment of credit policy-organization of a standard merchandising program as well as the delivery schedules.

Tulsa Boiler Is Renamed Flint Steel Corporation

Flint Steel Corporation is the new business name to replace Tulsa Boiler and Machinery Company of Tulsa. The change applies to the name only, and will not affect the ownership, management, personnel, or operating policies of the company, Charles W. Flint, president, emphasized.

Monsanto Establishes Texas Sales Office

Monsanto Chemical Company, St. Louis, has established a Texas sales office in Houston with Harvey M. Harker as general branch manager.

Harker, who first worked for the company in 1918 as an assistant plant manager, rejoined the company in 1926 as director of purchases. He has been assistant general sales manager of the orchanical chemicals division, St. Louis, since 1931.

His assistant in the Texas office will be Kenneth O'Connor, who will have charge of office operations.

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